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THE EFFECT OF YELLOW PINE (*PINUS PONDEROSA* LAWS) NEEDLES ON THE REPRODUCTIVITY OF THE LABORATORY FEMALE MOUSE[1]

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ABSTRACT

The present study shows that a specially prepared aqueous fraction of yellow pine needles contains a factor(s) that depresses the uterine weight of immature mice while the prepared ether fraction contains a compound(s) that is toxic to such mice. This toxicity varies from month to month throughout the year; the greatest degree of toxicity is noticeable in those needles collected during the winter. Both the aqueous and ether extracts caused a depression of the metabolism of weanling mice. The block in metabolism was removed, however, within 8 hours after the last administration of the extracts. Both extracts contributed to embryonic mortality in the mouse and both reduced fœtus weight. In addition, the parent liquor appeared to be responsible for a decrease of the uptake of I^{131} by the thyroid gland of the weanling mice.

INTRODUCTION

During the past few years a research program has been under way at the laboratory of the Division of Animal Science at the University of British Columbia, Vancouver, B.C., to study the estrogen-like activity of certain legumes and grasses grown for forage in British Columbia (5, 6). These studies, as well as investigations elsewhere (1, 3, 4) have shown that the estrogenic compounds present in a number of forages appear to be the cause of various reproductive disorders in farm animals.

From numerous reports of beef cattle producers throughout the interior of British Columbia and the northwestern United States, as well as the work conducted by MacDonald (8) and Nicholson[4], it is indicated that pregnant beef cows tend to abort when they consume yellow pine needles. This information stimulated the thought that these needles may contain estrogenic and/or "anti"-estrogenic substances. The present study was undertaken to determine the effects of yellow pine needles on the uterus and reproductive performance of the laboratory female mouse. The mouse was chosen because of its rapid breeding behaviour, and thus the results obtained may be used as a guide for future studies with the beef animal.

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MATERIALS AND METHODS

Plant Material

Samples of yellow pine needles (*Pinus ponderosa* Laws) were collected each month from March 1959 to February 1960, inclusive, at Cherry Creek, British Columbia. Most of the representative samples were obtained from trees approximately 20 feet in height; all the samples were taken from branches below the maximum reach of a grazing animal. No more than a dozen tips were taken from any one tree so as to maintain the heterogeneity of the sample. The samples were shipped in burlap sacks by rail express and were chemically extracted within a week after arrival at the laboratory.

Experimental Animals

Randomly selected immature female mice (8-12 grams) of the U.B.C. Swiss albino strain were used to determine the estrogenic activity of the plant material and for the determination of thyroid activity. Mature virgin female mice of the same strain were used to study the effects of the extracts of yellow pine needles on embryonic mortality. Male animals were all proven sires from the same stock. All animals were housed in enamel crisper dishes containing woodshavings. Animals were housed individually with the exception of those used for the bioassay procedures, which were housed in groups of 12.

Extraction of Plant Material

A modification of the extraction procedure outlined by Bickoff *et al.* (2) was used. The pine needles, stripped from their stems, were macerated in an electric grinder and blended with acetone in a food blender for 2 minutes. The mixture was then filtered and the filter cake washed thoroughly with additional acetone. The filtrate was concentrated under vacuum to leave essentially an aqueous concentrate. The concentrate was extracted four times with ethyl ether. The ether extract was evaporated to dryness under vacuum; the solid residue was then dissolved in a minimum of acetone and added to a basal mouse ration (5), so that 1 gram of the ration contained the extractives from 2 grams of the original dried plant material (2:1). The aqueous fraction obtained was added to basal mouse ration in the same fashion as the ether extract to obtain a 2:1 ratio.

Bioassay Procedure

The estrogenic activity of the aqueous and ether fractions of monthly samples (March 1959 to February 1960) of the yellow pine needles was determined by the method outlined by Kitts *et al.* (5).

Embryonic Mortality Experiment

One hundred female mice were randomly selected and allowed to breed from 5 p.m. to 8 a.m. the following morning. Only females with vaginal plugs less than 0.25 inches from the vaginal orifices were used in the study. Females bred by each sire were randomized among five groups. The design of the experiment was as follows:

Control Group — basal ration fed *ad libitum.*

Aqueous Group — basal ration fed *ad libitum* for 4 days*; aqueous fraction of August 1959 yellow pine (1:1 on dry matter basis) *ad libitum* for remainder of gestation period.

*Feeding of aqueous fraction commenced subsequent to theoretical implantation time (10).

Restricted Control Group – basal ration *ad libitum* for 4 days; basal fed at 5.5 grams/day/mouse for remainder of gestation period.

Ether Group – basal ration fed *ad libitum* for 4 days; ether fraction of August 1959 yellow pine (1:1 on dry matter basis) *ad libitum* for remainder of gestation period.

Thyroid Activity Experiment

Thirty immature female mice were randomized into three groups (Table 3). Twenty-eight hours after the animals were placed on the experimental rations they were injected intraperitoneally with 0.50 millilitres of Na I^{131} in sodium bisulphite carrier diluted with distilled water. This volume represented 10 microcuries of I^{131}. All rations remained with the mice until the time of sacrifice 19.5 hours after the injection of the Na I^{131}. At this time the animals were weighed and dissected. The thyroid glands were removed *in situ* with the tracheae and placed, dorsal side up, in petri dishes dampened with 10 per cent formalin in physiological saline. The I^{131} activity of each thyroid was determined using a Nuclear Chicago model DS5 versatile scintillation detector attached to a model 151 decade scaler. After 7 days in the fixative the tracheae were removed from the thyroids and the glands weighed. The activity of each thyroid was then calculated in terms of counts per minute per unit fixed thyroid weight.

RESULTS AND DISCUSSION

Bioassay of Yellow Pine Needle Extracts

The results of the bioassays of the samples of yellow pine needles are given in Table 1. In all cases uterine weights (expressed as a per cent of body weight) of the mice fed the aqueous fraction were lower than those of the corresponding ether fraction. Although there were only three samples in which the mean uterine weight of the mice offered the aqueous fraction was significantly lower ($P = 0.01$) than the corresponding mean uterine weight of the mice offered the ether fraction, it is quite possible that there would have been a greater number significant at $P = 0.01$ if the bioassay period had been extended beyond the 80-hour period. The results of the bioassays also showed a definite trend towards increased toxicity of the pine needles with progress of winter, and presumably also of dormancy. In addition, toxicity appeared to be greater in the ether fraction than in the aqueous layer. The discrepancies that appear in April, August, September, November and December samples (Table 1) may be due to incomplete separation of the two layers during the extraction process. These months' samples appeared to require only 8 hours for complete separation to take place, while in the other month's samples the separation of the ether washings required a longer period of time (4 days).

It was interesting to note that by the second day of the bioassays the mice on the aqueous and ether fractions exhibited reduced activity and lowered body temperature, the latter determined by touch. After these animals were fasted for 8 hours, their body temperatures returned to normal. Thus, it can be assumed that the majority of the deaths that occurred were

TABLE 1.—MONTHLY BIOASSAY OF YELLOW PINE NEEDLES (2:1 ON DRY MATTER)

Month	Uterine weight as a per cent of body weight		Standard error		Number of deaths per 12 mice		Total feed eaten (grams)	
	Water layer	Ether layer	Water layer	Ether layer	Water layer	Ether layer	Water layer	Ether layer
1959								
March	.1132[2,3]	.1386	±.0056	±.0060	0	2	49	44.5
April	.1325[2]	.1694	±.0070	±.0060	2	0	48	53
May	.1216[2]	.1641	±.0060	±.0118	1	1	51	49
June	.1266	.1374	±.0082	±.0100	0	6	60	39
July	.1136[3]	.1415	±.0070	±.0093	0	0	45	50
August	.1245[1, 3]	.1619	±.0038	±.0058	2	3	47.5	47.5
Control	.1515		±.0088		0		60	
September	.1643	.1805	±.0057	±.0118	8	8	8	43
October	.1520	.1672	±.0053	±.0138	0	3**	50	28
November	.1844	.2271	—	±.0251	8*	8	30	46
December	.1635	.1741	±.0136	±.0114	9	4	29	51
1960								
January	.1450[1]	.1907	±.0089	±.0063	1	9	49	38
February	.1259[1]	.1945	±.0055	±.0103	0	6	54	49
Control	.1627		±.0096		0		60	

[1]Significantly different (P = 0.01) than corresponding ether layer
[2]Significantly different (P = 0.05) than corresponding ether layer
[3]Significantly different (P = 0.05) than corresponding ether layer

*Out of 10 mice
**Out of 6 mice

not a direct result of the reduced feed consumption of the experimental rations, but due to some compound or group of compounds in the prepared feed.

Effects of Yellow Pine Needle Extracts on Embryonic Mortality

Pregnancy of the mice on test was determined by the presence of a blood clot in the vagina on the 11th day after the vaginal plug was observed. The mice not pregnant at day 11 were sacrificed and observed for resorption sites and corpora lutea. On the 18th day the pregnant animals were dissected. Implantation sites, resorption sites, corpora lutea and fœtus weights were recorded.

Preliminary experiments preceding the above experiment showed that dams which started consuming the aqueous pine extract 4 days after observation of the vaginal plug exhibited the greatest deviation from the controls both in percentage of fœtuses resorbed and pregnancies at 11 days. In this case, the change from the control ration to the experimental ration was during or just after the theoretical implantation period of the embryo. McClure (9) noted that starvation for 48 hours over the time of implantation greatly reduced the subsequent number of pregnancies. On the other hand, starvation for 24 hours during the same portion of the gestational period did not hinder the reproductive processes of the mice. When specific rations were changed at this time, causing the mice to go temporarily off feed, it is doubtful whether they would have fasted for more than 24 hours. Therefore, it is assumed that it was not the change of rations at this critical period that hindered the reproductive performance of this group.

The results of the effects of various extracts of yellow pine needles on the developing embryos of the mice are presented in Table 2. On the basis of the feed consumption the group on the aqueous fraction can best be compared with the control group on *ad libitum* feeding (Table 2). Similarly, the ether and acetone groups can best be compared with the control group on reduced feed consumption.

Only 16 per cent of the ether group were pregnant on the 11th day. Because the ration was not fed until after the theoretical implantation time, it seems reasonable to suggest that the majority of the mice had completely resorbed their young even though resorption sites were not evident. Supporting this statement was the physical appearance of many of the uteri at the time of dissection. The vascularization of the uteri was in a banding pattern – possibly an indication that resorption had just been completed*. The acetone group, but not the aqueous group, showed a similar pattern.

The acetone group had the lowest percentage of mice pregnant at 11 days. This is not difficult to understand because the acetone extract was the parent liquor from which both aqueous and ether extracts were obtained. This could mean that the compounds in both the latter fractions had an additive effect. On the other hand, the fact that less of the acetone

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TABLE 2.—THE EFFECT OF VARIOUS EXTRACTS OF AUGUST 1959 YELLOW PINE ON THE DEVELOPING EMBRYOS OF THE LABORATORY MOUSE[1]

Ration	No. of dams bred	Average feed consumption per day (gm.)	No. dams pregnant (11 days)	Per cent dams pregnant (11 days)	No. dams pregnant (18 days)	Total number fœtuses	Mean weight of fœtus (gm.)	Standard error of means
Control	19	7.7	14	74	14	149	1.19 } P=0.01	±0.033
Aqueous (1:1)**	20	7.9	10	50	9	85	1.04 }	±0.046
Control-feed restricted	20	5.5	11	55	8	72	1.18 } P=0.03	±0.054
Ether (1:1)	19	5.7	3	16	2	32	1.01 }	±0.010
Acetone (1:1)	20	4.6	2	10	—	—	—	—

[1]Animals were fed experimental rations just subsequent to the theoretical implantation time
**(1:1) = designates 1 gm. ration is equivalent to extract from 1 gm. of forage dry matter

TABLE 3.—THYROID ACTIVITY

Ration	Average body weight at start (gm.)	Average loss in weight (gm.)	Total feed consumed (gm.)	Counts/minute/unit fixed thyroid weight ± S.E.
Control	11.2	0.8	4	7816 ± 831
August 1959 pine (acetone 1:2)*	11.1	1.3	3.7	3575 ± 498
December 1959 pine (acetone 1:2)*	11.1	1.4	3.8	5040 ± 666

*(1:2) = designates 1 gm. of ration contains the extractives from 0.5 gm. forage dry matter

ration per mouse was consumed may have contributed to the adverse effects noted in this group.

The weight of the fœtuses from the aqueous group were lower ($P = 0.1$) than the *ad libitum* controls; those from the ether group were significantly lower ($P = 0.03$) than the restricted controls. The factor(s) responsible for the suppression of fœtus weights appeared to be present in both the aqueous and ether fractions. Preliminary experiments also showed that the earlier in the gestation period the aqueous fraction of yellow pine was fed, the smaller were the resulting fœtus weights.

Thyroid Activity

The results obtained from this study (Table 3) indicate that, in the immature mice, the acetone extracts of the pine samples appeared to be responsible for a decrease in the uptake of I^{131} by the thyroid gland. The uptake values obtained from the thyroids of the August group were significantly ($P = 0.01$) lower than those of the control group. The more dormant needles of the December sample did not depress the uptake of I^{131} as much as the August sample at this low level of feeding. The possibility of any additional stress factor(s) contributing to this apparent decrease in thyroid activity must not be overlooked. Further study on this subject is necessary before a firm conclusion can be made regarding the effect of chemical extracts of yellow pine needles on thyroid activity of the animal.

SUMMARY

Both aqueous and ether extracts appeared to affect weanling female mice; the aqueous layer depressed the uterine weight, while the ether layer increased the incidence of mortality. All three extracts of the yellow pine needles, viz. acetone, aqueous and ether, appeared to interfere with the reproductive performance of the female mice. The possibility that the active compounds in the extract acted through the thyroid gland was investigated using radioactive I^{131}. Additional experimentation is under way to determine more completely the relationship of these compounds on the thyroid gland.

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THE BREEDING POTENTIAL OF FULL SISTERS IN THE DOMESTIC FOWL[1]

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ABSTRACT

The breeding potential of low and high egg producing full sisters was determined with Barred Plymouth Rocks. The average egg production for each group of full sister dams was the dividing line between low and high dams. All the individuals in a group of full sisters were mated to the same male, and the progeny from all groups were randomized among the laying pens.

The average yearly egg production of the progeny of low and high dams was 220.5 and 227.5 eggs respectively. The difference of 7 eggs in favour of the progeny of high dams was highly significant.

Family selection would be less effective than individual selection in the population under consideration. Most progress would likely be made where selection is based on individual merit plus some attention to the average merit of the family.

INTRODUCTION

The individual's own performance has been the basis of selection for many years, when breeding for egg production. This is known as mass selection. Family testing, which is generally considered an improvement over mass selection, has gradually gained recognition and has increased in popularity to the point where, in some cases, the performance of the individual is neglected entirely. Much information is available regarding methods of selection, but complete empirical verification of many plans is lacking. In this connection an experiment which involved a progeny test of full sisters mated to the same male was conducted at the Research Station, Fredericton, New Brunswick. The work was carried on for 4 years.

A brief review of the early work on breeding for egg production is appropriate for this study. The results of Gowell's work in 1898 at the Maine Agricultural Experiment Station were reported by Pearl and Surface (8) who found that daughters of 200 egg dams laid no more eggs than pullets from dams with records of 150 to 200 eggs. At the same Station, mass selection failed to improve mean winter egg production, but a remarkable increase was achieved by Pearl (7) in his first year of progeny testing. These results have been used to support the claim that mass selection is ineffective in breeding for egg production.

Dryden (1) on the other hand demonstrated, at the Oregon Experiment Station, that egg production could be increased by mass selection. He selected breeding hens according to their individual trap-nest records and males on the basis of the records of their dams. In 10 years, the mean egg production was raised from 86 to 215 in Barred Rocks, from 135 to 231 in Oregons, and from 107 to 212 in White Leghorns. The greatest progress was made in the earlier years of selection when average production was low. No progress was made after production reached about 200-220 eggs. This has been the experience of many breeders and is discussed in some detail by Hutt (3).

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[1]Contribution No. 17, Research Station, Canada Department of Agriculture, Fredericton, N.B. A portion of the data and material in this paper is taken from a thesis previously presented in partial fulfilment of the requirements for the degree of Master of Science, McGill University, Montreal, Que.

Munro *et al.* (6) analysed the pedigree records of seven Dominion Experimental Farm flocks and calculated regression of daughters on dams for egg production. He concluded that the small size of the pooled net regression coefficient, viz. 0.153, shows that, in flocks wherein females laying 200 or more eggs are used exclusively as breeders, selection of dams on the basis of their trap-nest record is not a practical procedure towards the segregation and concentration of high transmitting ability.

Lush (5) has shown that for family selection to be more effective than individual selection family members must resemble each other genetically much more than they do phenotypically. He pointed out that mass selection results in choosing some of the same individuals as would be chosen under family selection. If either method is absolutely ineffective the other will be also. Most progress is likely to be made where some attention is paid to individual merit plus some attention to the average merit of the family.

Lerner *et al.* (4) computed estimates of heritability, from full sister groups, for egg production, egg weight and sexual maturity. The relative amount of attention to be paid to individual and family selection is shown to be a function of the degree of heritability and of family size.

EXPERIMENTAL

The experiment was designed primarily to determine if there is a difference in breeding potential between low egg producers and their high egg producing full sisters; hence each set of matings consisted of one or more dam families mated to the same male. The experiment was conducted over a period of 4 years but the matings each year were made independently of the previous year's results; that is, each family of dams was selected for mating solely on the basis of a suitable number of individuals in the family, and without regard as to whether the family of dams originated from a low or a high dam the previous year. The data collected for 4 years were pooled for analysis and consideration of results. The average egg production for each group of full sister dams was the dividing line between low and high sisters for purposes of comparing results. The families averaged 2.0 low dams and 2.2 high dams for each family which produced progeny for the test. There was an average of 7.5 daughters completing the egg production progeny test from each dam. The number of dams which produced a sufficient number of progeny to be included in the experiment is shown with the average egg production of the dams in Table 1. The number of progeny with their average egg production is shown in Table 2.

Close inbreeding such as dam and son matings were avoided, but in the first year of the experiment both males and females were selected from the Station flock of Barred Plymouth Rocks. There had been no outside blood introduced into this flock for 3 years but previous to this time one or two males from the Central Experimental Farm were generally used each year in addition to those from the Fredericton flock. Two males from the Central Experimental Farm were again used in the second year of the experiment in an attempt to improve fertility which was only 71.2 per cent the first year. The average fertility was still only 64 per cent the second

TABLE 1.—DAM POPULATION AND EGG PRODUCTION

Year	Number of dam families	Low dams (Below family av.)		High dams (Above family av.)	
		No.	Eggs	No.	Eggs
1948	6	9	216	14	275
1949	14	19	209	21	262
1950	10	18	192	25	265
1951	15	38	182	41	245
Total (or) Average	45	84	194	101	258

TABLE 2.—PRODUCTION OF PROGENY

Year	All progeny		Progeny of dams Below family av.		Progeny of dams Above family av.	
	No. birds	Average no. eggs	No. birds	Average no. eggs	No. birds	Average no. eggs
1948	181	229.8	70	223.7	111	233.6
1949	347	203.2	160	196.8	187	208.8
1950	367	229.9	137	227.0	230	231.6
1951	551	232.6	257	230.9	294	234.0
Total (or) Average	1446	224.5	624	220.5	822	227.5

year, however, and two males unrelated to the flock were used to supplement the Station males in each of the 2 remaining years. Fertility was 91.6 per cent in the last year of the experiment.

Egg production data were obtained from trap-nest records in the first laying year, that is, in the 365-day period from the time each pullet laid her first egg. Annual egg production was calculated from actual trap-nest records up to September 4, the required number of eggs being added to this record to complete the full year, as suggested by Gutteridge and O'Neil (2). Trapping was conducted daily in 1948, 6 days a week in 1949 and 1950, and 5 days a week in 1951. The egg records from only those pullets surviving until September 4 were included in the progeny records. Pullets from all families were randomized among the laying pens.

The records from pullets laying less than 100 eggs up to September 4 were discarded since unpublished records compiled at the Central Experimental Farm indicate that the majority of such birds have some physiological defect. Whatever the merits, or otherwise, of using survivor production and eliminating extremely low producers, it is improbable that the results would be biased by such practices because laying-house mortality for the pullets used in this experiment was only 8.8 and 11.5 per cent for the low and high groups respectively, and of the 20 pullets with records under 100 eggs 12 were progeny of high dams and 8 the progeny of low dams.

As previously noted, fertility was low during the first 3 years of the experiment and the number of dams with a sufficient number of progeny for a test was lower than anticipated (Table 1). Steps were taken to improve fertility which was 91.6 per cent for the flock in the final year of the experiment when progeny tests were obtained from 79 dams. In an attempt to secure large families for each succeeding year's work, the hatching season was extended for a period of 7 weeks through March and April for the first 2 years of the experiment and into May for the third year. The pullets hatched for the final year's test were all obtained from three hatches during the month of April.

All pullets reared were used in the progeny test (i.e., there was no culling after the families were selected for the test). Some chicks were discarded at time of hatching, however, on the following basis: All chicks were discarded from families which did not produce progeny from both high and low dams. In other cases all the chicks from one hatch within a family of dams, usually the first or last hatch, were discarded in order to more nearly balance the progeny between the dams. No other attempt was made to correct for date of hatch. The progeny of all dams with less than four pullets were also discarded. There was an average of 7.8 pullet progeny for each dam tested. The practice of discarding all dams with less than four pullets could conceivably introduce a bias but it was thought advisable because at least four daughters were considered necessary to give a reliable estimate of the dam's worth.

RESULTS AND DISCUSSION

With the exception of low fertility in the breeding-pens, which eliminated a number of potential dams from the full sister groups, the experiment progressed favourably throughout the period under consideration. There were no disease outbreaks at any time, with the exception of a mild coryza in the first 3 years, and laying-house mortality was only 10.2 per cent. The average production of 224.5 eggs for the flock indicates satisfactory performance. The average egg weight was the same for the progeny of high dams as for the progeny of low dams, i.e. 60.7 grams; hence this trait would not affect the relative number of eggs laid between the two groups of progeny and is not given further consideration.

TABLE 3.—ANALYSIS OF VARIANCE

Source	D/F	Mean square
Total	184	472.77
Between matings (family groups)	44	644.26**
Between levels production	1	1392.4**
Matings x levels production	44	149.61
Remainder	95	155.2

**Significant at P = .01

TABLE 4.—AVERAGE EGG PRODUCTION WITH DIFFERENT METHODS OF SELECTION[1]

Year	No selection	Individual selection		Family selection		Selection within families	
	Progeny of all dams	Progeny of dams below average	Progeny of dams above average	Progeny of families below average	Progeny of families above average	Progeny of dams below family average	Progeny of dams above family average
	eggs	eggs	eggs	eggs	eggs	eggs	eggs
1948	229.8	228.4	230.8	229.9	229.6	223.7	233.6
1949	203.2	197.9	207.4	204.2	202.1	196.8	208.8
1950	229.9	225.8	232.4	229.0	231.1	227.0	231.6
1951	232.6	231.6	233.3	231.4	233.9	230.9	234.1
Average	224.5	221.8	226.5	224.3	224.7	220.5	227.5

[1] These egg production data are obtained from matings designed to evaluate the breeding potential of full sisters. The progeny records have been arranged to show what would be obtained with the various methods of selection indicated.

The data collected during the 4 years of the experiment with regard to yearly egg production of survivors were combined and subjected to analysis of variance. The method used was that suggested by Pearson and Bennett (9) for unequal groups. The analysis of variance (Table 3) shows that the difference of 7 eggs obtained from the progeny of dams above the family average over the progeny of dams below the family average was highly significant as indicated by the variance for between levels of production. The variance for between matings shows that there was also a real difference in egg production between the progeny of full sister groups of dams but this is of little importance since there were progeny from both low and high dams in each family tested. The variance for sires was not removed because, in 26 of the 45 families tested, a separate male mated each family; thus sires and families (matings) were removed as one source of variance. Similarly, inter-year effects were not removed because it was impossible to repeat the same matings each year and the inter-year effects could be largely due to the different matings.

The significant difference of 7 eggs between the progeny of low and high producing full sister dams prompted an attempt to evaluate the effectiveness of whole family selection and of individual selection, regardless of family. The pooled data for these calculations were obtained from the matings previously described, and there was, therefore, no cumulative effect of any type of selection. The general flock average among the dams was the dividing line where selection was considered to have been carried out for low and high dams under individual selection. The same flock average was the dividing line between the low and high dam family means under whole family selection (Table 4). While the type of mating employed, i.e. the members of each family being mated to one male, was probably not the most desirable for a progeny test of this kind, it is of interest to note that individual selection would be fairly effective with this population; family selection would be less effective and individual selection within families most effective.

Under individual selection, progeny of dams above the flock average produced 2 eggs more per year than the progeny of all dams, while under whole family selection progeny of families above the flock average produced 0.2 eggs more than the progeny of all dams. These small differences, allowing for some sampling error, indicate that for practical purposes neither whole family selection nor individual selection could be considered very effective in a population such as this. Most progress would likely be made where selection was based on individual merit, plus some attention to the average merit of the family.

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FURTHER STUDIES ON RAISING DAIRY CALVES WITH LIMITED AMOUNTS OF MILK[1]

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ABSTRACT

Ninety-four Holstein heifer calves were used in five experiments to study the effects of different rates and methods of feeding whole milk on body growth rate.

Calves fed whole milk at a rate of 8 pounds per head daily until 4 weeks old and none thereafter made as rapid growth to 16 and 52 weeks of age as those fed milk at a rate of 10 per cent of body weight. Calves weaned from milk abruptly when 4 weeks old grew as fast thereafter as calves receiving the same total quantity of milk but weaned gradually. Inoculation of calves with cuds at frequent intervals did not increase rate of body gain.

Calves that received 6 pounds of whole milk daily until 4 weeks old and none thereafter gained as well as those that received 8 pounds of whole milk until 4 weeks old or those that received 6 pounds of whole milk daily until 8 weeks old. The inclusion of 10 per cent skim milk powder in place of linseed oilmeal in the starter did not improve gains.

INTRODUCTION

A previous study of Whiting and Clark (21) indicated that Holstein heifer calves weaned from whole milk when 4 weeks old and fed a plant protein calf starter (21 per cent protein) and alfalfa hay grew at a similar rate (body weight, height at withers, and heart girth) to 1 year of age as did calves weaned from whole milk at 4 weeks and then fed skim milk plus a grain mixture and alfalfa hay to 16 weeks of age.

Preston (15) and Quayle (18) have reported no differences in gains when comparing calves weaned abruptly from milk when 3 to 4 weeks old to those weaned gradually. In another experiment, Preston (16) reported that Ayrshire calves were successfully raised when fed milk at the rate of 8 per cent body weight to 3 weeks of age and then weaned abruptly.

Pounden and Hibbs (13, 14) have reported that inoculating calves with cuds taken from mature cows establishes a rumen flora at an earlier age and enables the calf to make greater use of feed. However, other workers (6, 10, 12) have found no benefits from cud inoculation.

In view of the previous results at the Research Station, Lethbridge, Alberta, and because of the findings of other research workers, a number of calf feeding experiments were conducted. One experiment was conducted to determine whether calves fed a uniform daily amount of whole milk grew as well as those fed milk at the rate of 10 per cent of body weight. Other experiments were carried out to determine the advisability of weaning calves from milk abruptly; to learn if the amount of whole milk fed could be reduced below 8 pounds per head per day without retarding growth; to determine whether cud inoculations increased the growth rate of calves fed limited amounts of milk; and to compare skim milk powder with linseed oilmeal as a source of protein for a calf starter. The results of these experiments are reported in this paper.

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PROCEDURE

The heifer calves used in the experiments were from the Holstein herd at the Research Station, Lethbridge. Each calf was left with its dam for 3 days and then placed in an individual pen. Whole milk, the amount of which varied between experiments, was fed in two equal feedings at approximately 8.00 a.m. and 5.00 p.m. When the calves were 1 week old they were offered a plant protein calf starter in pelleted form and good quality alfalfa hay. The calf starter was composed of 32 pounds of oats, 5 pounds of barley, 10 pounds each of wheat, wheat bran, and linseed oilmeal*, 17.5 pounds of soybean oilmeal, 5 pounds of alfalfa meal, 8 pounds of beet molasses, 2.5 pounds of mineral mixture, 100,000 I.U. of vitamin A, 20,000 I.U. of vitamin D_2, and 50 milligrams of riboflavin. The mineral mixture contained 40 pounds of bonemeal, 40 pounds of salt, 20 pounds of ground limestone, 2 grams of cobalt sulphate, 4 grams of copper sulphate, and 40 grams of ferrous sulphate. The calf starter contained approximately 21 per cent protein, 6 per cent fat, and 9 per cent crude fibre. Starter consumption was limited to a maximum of 4 pounds per head daily and was fed until the calves were 16 weeks old. Good quality alfalfa hay was fed *ad lib.*

When each calf reached 16 weeks of age, individual feeding was discontinued and it was placed with 4 to 6 other calves of approximately the same size. Calves that reached 16 weeks of age during the spring and summer months were placed on pasture and those that reached 16 weeks during the fall and winter months were continued on alfalfa hay. In addition, each calf received, until 1 year old, 4 pounds daily of a concentrate mixture (68 pounds oats, 10 pounds barley, 10 pounds wheat bran, 10 pounds linseed oilmeal, 1 pound bonemeal, and 1 pound cobaltized-iodized salt).

All calves were weighed at birth, and at weekly intervals until 16 weeks old, and thereafter at 2-week intervals until 1 year old. Height at withers and heart girth measurements were taken at each weighing. Body weights and measurements were adjusted for differences in birth weights and measurements by analyses of covariance (20) before testing for significance between lots.

Experiment 1

In Experiment 1, twenty-four 3-day-old heifer calves born during 1954 were alternately allotted to one of two lots (A and B). Whole milk was fed to each calf in Lot A at the rate of 8 pounds daily, until it was 25 days old, after which the amount was reduced every second day by 2 pounds. Whole milk was fed to each calf in Lot B at the rate of 10 per cent of body weight (taken at the beginning of each week) until 25 days old and then the milk was uniformly reduced so that the calf was weaned when it was 31 days old.

Six calves picked at random from each lot received cud inoculations when 1 week old and twice weekly thereafter until 4 weeks old. The cuds were taken from mature dairy cows.

*In Experiment 5, the linseed oilmeal was replaced by skim milk powder for Group L calves.

Experiment 2

In Experiment 2, fourteen 3-day-old heifer calves born during 1955 were alternately allotted to two lots (C and D) of seven calves each. The calves in Lot C were fed 8 pounds of whole milk daily until 4 weeks old and none thereafter, and those in Lot D were fed 8 pounds of whole milk until 1 week old, 6 pounds daily from 1 to 3 weeks, 4 pounds daily from 3 to 5 weeks, and 2 pounds daily from 5 to 7 weeks of age. Each calf in each lot received a total of 200 pounds of whole milk.

Experiment 3

In Experiment 3, sixteen 3-day-old heifer calves born during 1956 were allotted alternately to two lots (E and F) of eight calves each. The calves in Lots E and F were fed 8 and 6 pounds, respectively, of whole milk daily until 4 weeks old and none thereafter.

Experiment 4

In Experiment 4, sixteen 3-day-old heifer calves born during 1956 and 1957 were allotted alternately to two lots (G and H) of eight calves each. The calves in Lot G were fed 6 pounds of whole milk daily until 4 weeks old, and those in Lot H were fed 6 pounds daily until 8 weeks old and none thereafter. More milk was fed to the calves in Lot H than to the calves in other lots, since those in Experiment 3 did not grow as rapidly as those in Experiments 1 and 2 and it was considered important to determine whether this was caused by an insufficient quantity of milk being fed.

Experiment 5

In Experiment 5, twenty-four 3-day-old heifer calves born during 1957 and 1958 were allotted at random to three lots (J, K, and L) of eight calves each. The calves in Lot J were fed 6 pounds of whole milk daily until 4 weeks old, and those in Lots K and L were fed 6 pounds of whole milk daily until 14 days of age and 5 pounds per head daily from 15 to 24 days of age and no milk thereafter. Skim milk powder replaced the linseed oilmeal in the calf starter fed to the calves in Lot L.

RESULTS AND DISCUSSION

Results are summarized in Table 1, in which body measurement data (moving average) for calves of the same ages taken from the "Beltsville" (9) and "Nebraska" (5) growth standards for Holstein heifers are listed for comparison. These data are adjusted to the same age in weeks as the calves in the present experiment by the average daily increases in weight or body measurement shown in the publications (5, 9).

In Experiment 1, calves fed whole milk until 4 weeks old at the rate of 10 per cent of body weight and none thereafter made the same body weight gains and increases in height at withers and in heart girth as calves fed milk at a maximum rate of 8 pounds daily. This was so, whether the data were adjusted or unadjusted for initial weights and measurements. Among the calves fed milk at a rate of 10 per cent body weight (Lot B) the smallest calf received 203 pounds of milk and the heaviest calf, 267 pounds. The calves in Lot A each received 200 pounds of milk.

If small calves are physiologically and/or chronologically younger at birth than larger calves of the same breed (2, 4, 7, 8), one might expect that small calves would require as much or more total milk to supply their nutrient requirements before they could utilize calf starters and roughage to the same extent as heavier calves. To test this supposition, regression coefficients were determined for 16-week body weights on birth weights. These were 2.29 and 2.31 for the calves in Lots A and B, respectively, which indicated that differences in milk intake of the order found in Experiment 1 did not influence weight gains. It would seem, therefore, convenient to feed all calves a uniform daily amount of milk, regardless of body weight.

Growth rates of calves in Lots A and B receiving cud inoculations were not significantly different to 16 and 52 weeks of age from those not receiving cuds (273 versus 275 pounds and 721 and 753 pounds at 16 and 52 weeks for those receiving no cuds and cuds, respectively). There were no differences in the appearance or apparent well-being of the calves between the two groups. This finding agrees with other reported work (6, 10, 12).

In Experiment 2, calves weaned abruptly from milk when 4 weeks old did not differ in body weight gains or measurements from those fed the same quantity of milk but in constantly diminishing daily amounts over a 7-week period. It was noted during the course of the experiment that the calves weaned from milk abruptly consumed dry feed more readily between 4 and 8 weeks of age than those continued on a small daily allowance of milk. Preston (15) and Quayle (18) have reported no differences in gains of calves weaned from milk gradually or abruptly at 3 to 4 weeks old.

Calves that received 6 pounds of whole milk daily to 4 weeks of age (Lot F) in Experiment 3 made as rapid growth (body weight gains and measurements) as those that received 8 pounds of milk daily to 4 weeks of age (Lot E). The calves in these two lots did not gain as rapidly as calves in previous experiments. The reasons for this were not apparent but may have been associated with year-to-year variations in feedstuffs, with sire differences, or with environmental variations. The calves in Lot C (Experiment 2) which were fed the same quantity of milk as those in Lot E (Experiment 3) were 15 pounds heavier when 16 weeks old and 79 pounds heavier when 52 weeks old. However, the calves in Experiment 3 did not eat as much feed, other than milk, as those in the previous experiments, as noted by total digestible nutrients (Table 1).

The calves in Lot G (Experiment 4) which received 6 pounds of whole milk daily until 4 weeks old made as rapid gains and increases in size as calves receiving 6 pounds of whole milk daily until 8 weeks old. This indicates that milk was not the limiting factor for growth of the calves in Experiment 3 as compared to those in Experiment 2, and that calves can be weaned at 4 weeks of age. Bell (1) found that the practice of discontinuing the feeding of milk substitutes at body weights of 145 to 150 pounds was preferable to weaning at a specific age.

TABLE 1.—THE AVERAGE WEIGHTS AND BODY MEASUREMENTS OF CALVES AND THEIR FEED CONSUMPTION AS INFLUENCED BY THE AMOUNT OF MILK FED AND BY ABRUPT VERSUS GRADUAL WEANING FROM MILK

	Experiment 1		Experiment 2		Experiment 3		Experiment 4		Experiment 5			Beltsville standard (9)	Nebraska standard (5)
	Lot		Lot		Lot		Lot		Lot				
	A	B	C	D	E	F	G	H	J	K	L		
No. calves per lot	12	12	7	7	8	8	8	8	8	8	8		
Average weight whole milk fed (lb.)	200	230	200	200	200	150	150	318	150	116	116		
Period of milk feeding (week)	4.5	4.5	4	7	4	4	4	8	4	3.5	3.5		
Daily rate of milk feeding (lb.)	8	10% BW	8	8→2	8	6	6	6	6	6→5	6→5		
Body weights (lb.)													
Birth	85	90	83	87	85	84	86	82	82	84	87	96	88
4 weeks	112	121	115	117	109	108	106	100	100	103	103	116	117
8 weeks	157	160	159	160	150	149	147	140	138	144	140	154	155
16 weeks	273	275	269	273	254	256	261	258	244	246	241	254	261
52 weeks	736	737	754	754	675	692	706	718	676	673	666	710	704
Height at withers (inch)													
Birth	28.9	29.2	28.7	29.1	28.4	29.0	29.0	29.0	28.4	28.9	29.0		29.1
4 weeks	30.7	31.5	31.0	30.9	30.2	30.6	30.9	30.3	29.8	30.6	30.4		30.4
16 weeks	36.7	37.0	36.6	36.6	35.6	36.2	36.7	36.4	35.8	35.8	35.5		35.9
52 weeks	46.8	47.6	47.1	46.6	45.8	46.4	46.6	47.0	46.1	46.4	45.7		47.0
Heart girth (inch)													
Birth	30.3	30.5	30.3	30.9	29.9	30.1	30.1	29.4	29.3	31.1	30.1		30.0
4 weeks	32.9	33.9	33.6	33.7	32.4	32.6	31.7	31.8	31.5	31.9	32.0		32.9
16 weeks	43.0	43.8	43.4	43.6	42.1	42.5	42.5	42.5	41.4	41.9	41.9		42.9
52 weeks	62.6	63.1	63.4	63.2	60.6	61.3	62.4	62.8	60.2	60.8	60.9		62.5
Feed consumption to 4 weeks of age (lb.)													
Milk (whole)	200	230	200	144	200	150	150	150	150	116	116		
Starter	10	10	14	14	8	14	13	10	6	16	14		
Alfalfa hay	4	6	7	7	4	5	3	2	3	5	5		
Feed consumption to 16 weeks of age (lb.)													
Milk	200	230	200	200	200	150	150	318	150	116	116		
Starter	351	347	319	314	301	316	306	268	289	318	306		
Alfalfa hay	158	166	208	194	157	183	204	173	160	150	152		
Total digestible nutrients (calculated)	355	361	358	347	320	335	339	324	305	315	307		

The calves in Lots K and L (Experiment 5) which received whole milk until 24 days of age made as rapid gains and increases in body measurements as those receiving milk until 4 weeks of age (Lot J). The substitution of skim milk powder for linseed oilmeal in the Lot L starter ration did not increase feed consumption or body growth. There was no advantage to including 10 per cent skim milk powder in the calf starter. This was different from the results obtained by Preston (15), who reported that calves fed the starter containing skim milk powder started to eat sooner, consumed more meal, and made greater average daily gains than calves fed a plant protein meal.

There were no significant differences in the increases of body weight, wither height, and heart girth due to the different treatments within each experiment.

The data presented in this paper confirm the findings of others (15, 16, 19), who have reported that dairy calves with body weights similar to those used in these experiments can be successfully raised (average daily gain of approximately 1 pound during the first 4 weeks of life) on as little as 6 pounds of whole milk daily. Since the normal, healthy calf is able to digest the dry matter of young grass and dry calf starter as efficiently when 3 to 4 weeks old as when older (11, 17), it does not appear to be necessary to feed whole or skim milk past 4 weeks of age, providing the calf is free from disease and is of normal body weight at birth.

Within recent years considerable evidence has accumulated to indicate that, on the basis of lifetime productivity, it may be desirable to restrict growth rate of dairy heifers during their growing period [see Crichton *et al.* (3) and references cited therein]. If these findings are further substantiated, a rapid rate of growth should not necessarily be used as a desirable criterion in determining the value of a feed or feeding system for growing dairy heifers, as it has been used in the past. If a less rapid rate of growth than that obtained in the present study (i.e., approximately 1.0 pound daily between birth and 4 weeks of age, 1.5 pounds daily between 4 and 8 weeks of age, and 1.8 pounds daily between 8 weeks and 1 year of age) is found to be desirable, it may be possible to further reduce the amount of milk and/or concentrate allowance required in the experiments reported in this paper to successfully raise dairy heifers.

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THE HERITABILITY OF VARIOUS TYPE COMPONENTS AND THEIR RELATIONSHIP TO PRODUCTION IN CANADIAN JERSEY CATTLE[1]

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ABSTRACT

The official type records of Canadian Jersey cows classified from 1946 to 1954 (inclusive) were analysed to determine the heritability of final or over-all type rating and ten of its components as listed on the Canadian Jersey Cattle Club type breakdown form. Records of all classified cows with official Record of Performance production were analysed to determine the relationship between type rating and production in the lactation nearest to date of classification.

The results of this study indicate that the within sire, within herd, heritabilities of type characteristics in Canadian Jerseys are relatively low, ranging from .07 for "rear udder" to .30 for "legs, pasterns and feet" with over-all type having a heritability of .24. There is a small, positive phenotypic correlation between type and milk production, and between type and butterfat production in the Jersey breed in Canada. The correlations range from .08 to .23 between various type components and production, with over-all type having a correlation of .16 to milk production and .20 to butterfat production. There is no significant correlation between type and butterfat test in this population of dairy cows.

INTRODUCTION

For many years body conformation has been used by dairy cattle breeders as a complementary aid to production records in the selection of breeding stock. Body conformation or "type" is also one of the bases of selection used amongst heifers before production records are available. For these reasons, as well as the fact that good type brings a premium on the market (10), the degree to which type is inherited as well as its relationship to milk and butterfat production is of considerable importance. To estimate the heritability of type and its relationship to production this study was undertaken using official type classification and Record of Performance data available on Canadian Jersey cattle.

The presence of a small, positive phenotypic correlation in various breeds between over-all type and milk and butterfat production has been found by Copeland (1), (2), Rennie (11), Stone (13) and Tyler and Hyatt (15). Recent studies by Grieve *et al.* (5), Mitchell *et al.* (9) and Johnson *et al.* (7) have shown that various components of over-all type have low but positive correlations with production ranging from .1 to .3.

Estimates of heritability of over-all type in dairy cattle have varied from almost zero to about .35 as found by Tyler and Hyatt (15), Harvey (6), Rennie (11), Stone (13) and Freeman and Dunbar (4).

Likewise, heritabilities of the type components which make up the various official type-score cards have ranged from less than .1 to .35, as shown by Freeman and Dunbar (4), Grieve *et al.* (5), Johnson *et al.* (7)

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and Mitchell *et al.* (9). All of these studies indicate that type as well as its various components is heritable to at least a small degree.

DATA AND METHODS

This investigation was based on data collected from the 9-year period 1946 to 1954 inclusive. The classification records were obtained from the files of the Canadian Jersey Cattle Club and the production records from the Production Service of the Canada Department of Agriculture. Data from 3,270 cows, distributed in 181 herds and classified for type on the same official type score-card form and having at least one Record of Performance production record, were used for estimating the phenotypic relationship between type and production. For estimating heritabilities, type and production records of 1,275 daughters and 934 dams were available.

Wherever possible, concurrent type and production records were used for the correlation and regression estimates. If a cow was not making a record when classified, then the record in progress nearest to the date of type inspection was used. Where cows had been classified more than once, the breakdown resulting in the highest final or over-all rating was used for the analyses. All production records were converted to a twice-daily-milking, 305-day, mature equivalent basis, using the conversion factors of Kendrick (8), Turner and Ragsdale (14) and Rennie (12). The data were placed on punch cards and subsequently analysed by means of electronic equipment in the Animal Breeding Laboratory of the Ontario Agricultural College. The main statistical tools employed were analysis of variance, regression, and correlation.

Intra-sire analyses tend to minimize the effect of environmental trends that might have occurred during the period studied (1946-1954). Prior to the extensive use of artificial insemination intra-sire analyses also removed most environmental differences between herds as well as differences existing between daughters of different sires. Through artificial insemination, which was used considerably during the latter part of the period studied, some sires had daughters distributed in more than one herd. To remove as much as possible the variation due to time trends, sires and herds, all analyses were conducted on a within sire and within herd basis.

The heritabilities in this study were calculated by doubling the intra-sire and herd regression of the type ratings of the daughters on the type ratings of their dams.

RESULTS AND DISCUSSION

Phenotypic Correlation between Type and Production and Regression of Production on Type

Table 1 shows the distribution of the cows in each type grade with their average production and percentage of cows in each grade with production records.

The fact that a higher percentage of the "Excellent" and "Very Good" cows had production records could be accounted for in two ways. First,

TABLE 1.—DISTRIBUTION BY OVER-ALL TYPE RATING OF COWS WITH ONE OR MORE PRODUCTION RECORDS AND THE AVERAGE PRODUCTION OF THE COWS IN EACH TYPE GRADE

Over-all type rating	No. of cows	Per cent of cows	Milk (lb.)	Fat (lb.)	Test (per cent)	Percentage of all classified cows with production records
Excellent	130	3.98	9,334	512	5.51	86.7
Very Good	1,183	36.18	8,434	460	5.48	81.5
Good Plus	1,364	41.71	8,024	437	5.48	73.2
Good	538	16.45	7,654	418	5.49	61.6
Fair	55	1.68	7,594	405	5.37	45.1
Averages	3,270		8,156	445	5.48	73.3

TABLE 2.—PHENOTYPIC CORRELATIONS BETWEEN THE TYPE COMPONENTS OF THE OFFICIAL SCORE-CARD AND PRODUCTION

Type component	Correlation coefficients[1]			
	Milk	95% Fiducial limits	Butterfat	95% Fiducial limits
Over-all rating	0.16	0.13 - 0.19	0.20	0.17 - 0.23
Head and neck	0.13	0.10 - 0.16	0.15	0.12 - 0.18
Depth and width of chest	0.09	0.06 - 0.12	0.13	0.10 - 0.16
Body capacity	0.12	0.09 - 0.15	0.14	0.11 - 0.17
Back and loin	0.08	0.05 - 0.11	0.11	0.08 - 0.14
Rump and tail setting	0.10	0.07 - 0.13	0.11	0.08 - 0.14
Breed and dairy character	0.16	0.13 - 0.19	0.20	0.17 - 0.23
Legs, pasterns and feet	0.12	0.09 - 0.15	0.16	0.13 - 0.19
Fore udder	0.09	0.06 - 0.12	0.12	0.09 - 0.15
Rear udder	0.20	0.17 - 0.23	0.23	0.20 - 0.26
Teats	0.15	0.12 - 0.18	0.19	0.16 - 0.22

[1]All correlations were highly significant at $P = 0.01$

cows in the higher grades may, in fact, have been higher producers, hence completed records more often than their lower classifying counterparts. Second, cows in the higher grades could have been given more opportunity to complete a production record because they were kept in the herd longer than lower classifying cows. It is impossible from these data to determine how much of this variation in percentage of classified cows with production records is due to each of these factors. From the data presented in Table 1 it would appear that the better type cows on the average tend to be higher producers and complete more records than those in the lower grades; however, the differences shown were not tested for significance.

Intra-sire, intra-herd phenotypic correlations between type components and butterfat test ranged from 0.00 to 0.05 and were neither of practical significance nor significant statistically at the 5 per cent level.

The highest correlations found (Table 2) were between production and "breed and dairy character", "rear udder", "teats" and over-all type rating. Considering over-all rating, in addition to the possibility of a very

TABLE 3.—REGRESSION OF PRODUCTION ON TYPE COMPONENTS

Type component	Regression	
	Milk (lb.)	Butterfat (lb.)
Over-all rating	408	24
Head and neck	362	20
Depth and width of chest	248	17
Body capacity	340	19
Back and loin	221	14
Rump and tail setting	233	13
Breed and dairy character	425	25
Legs, pasterns and feet	333	21
Fore udder	197	13
Rear udder	492	27
Teats	414	25

real association between dairy type in general and production, it is probable that dairymen select cows more intensively on over-all rating along with production than on any single type component. This would give a slight upward bias to this correlation compared to those of most of the components of over-all type rating. "Breed and dairy character" could be expected to have a relatively high correlation with production since heavier-producing cows usually acquire the lean, angular appearance that gives them a high rating in this section of the type breakdown. An anatomical difference could at least partly explain the difference in size of the correlations with production of "fore udder" and "rear udder". In general, more secretory tissue is present, resulting in more milk being produced in the rear quarters than in the fore quarters of the udder (3). Thus rear udder type could conceivably have more effect on production than fore udder type and make the correlation higher. The fact that butterfat production in every instance had a higher correlation with type than milk production might be the result of Jersey breeders selecting more intensively for butterfat production along with type than for milk production with type.

Regression coefficients were computed to give a practical value to the change in production over one lactation that might be expected with each change of one grade in type rating. Table 3 shows the intra-sire, intra-herd regressions of milk and butterfat production on type ratings. It is assumed that most good dairymen feed and care for their higher producers and superior type cows somewhat better than their poorer cows. Consequently, the correlations and regressions reported here may be biased upward. The magnitude of this error is not known.

These data indicate that, in general, a small, positive phenotypic correlation exists between the components of type and milk production, and type and butterfat production in Canadian Jersey cattle. Though good type and high production are sometimes combined in one animal, type is not in itself a very reliable indication of production.

TABLE 4.—HERITABILITIES OF TYPE COMPONENTS IN 1,275 CANADIAN JERSEY DAUGHTER-DAM PAIRS

Type component	Heritability	Standard error
Over-all rating	.24	± 0.07
Head and neck	.26	± 0.07
Depth and width of chest	.19	± 0.07
Body capacity	.28	± 0.08
Back and loin	.24	± 0.08
Rump and tail setting	.17	± 0.07
Breed and dairy character	.23	± 0.07
Legs, pasterns and feet	.30	± 0.08
Fore udder	.18	± 0.07
Rear udder	.07	± 0.07
Teats	.20	± 0.07

Heritability of Type

Heritabilities of over-all type rating and its ten components were calculated from the following formula:

$$\text{Heritability} = 2\,b$$

where b (regression coefficient) =

$$\frac{\text{Covariance of daughter's type rating x dam's type rating}}{\text{Variance of dam's type rating}}$$

The covariance term was calculated from 1,275 daughter-dam pairs, whereas the variance term was derived from 1,141 "dams' observations", each dam's rating being repeated for every new daughter by a different sire. There were actually 934 dams altogether in 156 different herds. Heritability estimates are presented in Table 4.

Some upward bias may be present in these estimates due to the inclusion of a fraction of the epistatic effects in the daughter-dam analysis as well as the possibility of some environmental correlation between daughter and dam. In most of the better managed herds, at least, there might be a tendency to provide the daughter of a cow with an environment similar to the dam, especially if the dam is outstanding in phenotype. Offsetting somewhat this upward bias is the possibility of breeders selecting dams on the basis of superior pedigree rather than superior phenotype. If such attention to pedigree were really effective, this might make the regression of offspring on parent lower than it would be if selection were on phenotype alone. This could occur in herds where attempts are made to "develop" cow families to enhance the sale value of the animals in that family.

Heritabilities of the various type components ranged from .07 for "rear udder" to .30 for "legs, pasterns and feet". This variation might be a result of several factors besides real differences in additive gene effects. A possible explanation of the difference in heritability between "fore udder" and "rear udder" is that classification inspectors may be more critical in rating fore udder than rear udder. Hence more error could be present in rear udder ratings than in fore udder ratings, resulting in a downward bias in the rear udder heritability estimate. Another factor adding to this downward bias is the probability that many daughters and dams were

classified at different stages of lactation, thereby introducing more error in the rear udder score.

More intense selection by breeders on certain type components may have reduced the phenotypic variance for the dams in these and biased upward their heritabilities. This could apply to "body capacity" and "breed and dairy character" since each of these components account for 20 per cent of the total score for type and hence may have undergone rather intensive selection in the dams. Heritabilities of all type components except "rear udder" are within the standard error of the heritability of over-all rating, i.e., $.24 \pm .07$, thus conceivably some of the variation between heritabilities could be due to sampling error. It is hard to explain the relatively high heritability of "legs, pasterns and feet" other than sampling error or a comparatively high proportion of additive gene effects. In addition, it is possible that at least a small portion of the variation between these estimates could be accounted for by varying epistatic effects which could not be eliminated entirely from a daughter-dam regression analysis.

The rather small size of the heritabilities in general indicates that selection based on phenotype alone will result in a relatively slow rate of permanent genetic improvement in any of these type components in the Jersey breed in Canada.

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THE EFFECTS OF SEX AND AGE OF MALE AT CASTRATION ON GROWTH AND CARCASS QUALITY OF YORKSHIRE SWINE[1]

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ABSTRACT

The effects of sex and age of castration of males on growth rate, feed efficiency and carcass characteristics in bacon type swine were measured using 16 pigs each as gilts, entire boars, and boars castrated at birth, 6, 12, 16, and 20 weeks of age. Castration at 20 weeks was too late since some pigs reached 200 pounds live weight before that age. Boars consumed less feed daily than barrows and gilts, were thinner in loin fat, and yielded a higher percentage of shoulder than gilts. The carcasses of boars and gilts were longer, had less fat covering over the shoulder and back, a larger area of loin, and a higher iodine number than those castrated late. Acceptability tests showed that sex or age of castration did not affect the flavour, odour, or tenderness of the meat.

Purebred breeders can delay castration for better selection of boars without any serious effect on growth, physical carcass characteristics, and feed requirements. Although the market discriminates against boars, it appears questionable whether castration is necessary when boars are slaughtered at 200 pounds before they reach the age of 150 days.

INTRODUCTION

Castration of the male pigs has long been considered indispensable in pork production. This view is held because of the fact that the edible flesh from boars may not be free from sexual odours and flavours. The general consensus is that castration should be performed at the age of 4 to 6 weeks. It is also suggested that the operation might be done when the animal is more fully developed. Hazel *et al.* (10) suggested delaying castration until the age of 112 days in order to use the gains from 56 to 112 days as a measure of hereditary growth in selecting boar pigs. They admit, however, that the operation might be slightly more difficult to perform at that time than at an earlier age.

Research has shown that the sex of an animal markedly influences its development. Chapel and Cabrera (3) found that boars and barrows gained faster than gilts. Other investigators, Bennett and Coles (1), Crampton (5, 6), and Crampton and Ashton (7, 8), have reported that barrows gained faster than gilts. On the other hand, Lucas and Calder (11) observed no significant difference in gains between sexes. Fredeen (9) and Crampton and Ashton (7) showed that females yielded longer carcasses with less fat and greater loin area. Bennett and Coles (1) found that carcasses from females were longer, heavier in shoulder and ham, lighter in middle, and had greater area of loin muscle than carcasses from barrows. The findings of Bratzler *et al.* (2) were that barrows castrated at 180 pounds and boars had a higher percentage of lean in the loin, a lower dressing percentage, and less back fat than pigs castrated at 70 days and 100 pounds.

This study was initiated to evaluate the effects of sex and age of male at castration on growth rate, feed efficiency, and carcass characteristics.

[1]Contribution from Research Branch, Experimental Farm, Kapuskasing, Ont. This work is part of a thesis submitted to the University of Minnesota in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

MATERIALS AND METHODS

Treatments and Experimental Design

One hundred and twelve pigs were used in this experiment, twenty-eight in each spring and fall of 2 years. The pigs were purebred Yorkshires raised at the Experimental Farm, Kapuskasing, Ontario. At birth, all males and female pigs of each litter on experiment were identified and weighed. The seven treatments under study consisted of males and females left entire throughout the experiment and males castrated at birth or at 6, 12, 16, and 20 weeks of age. Limitations in the number and size of the litters prevented the use of a randomized complete block design with litters as blocks. Consequently, a balanced incomplete block design with seven blocks and four treatments per block was employed. The basic design was repeated in the spring and fall of each 2 consecutive years. Each litter (4 pigs) was allotted at random to one of the incomplete blocks and within each block (litter) the pigs were assigned at random to the treatments.

Animal Management and Feeding Practice

The young pigs sucked their dam until the age of 8 weeks. When they were approximately 3 weeks old, creep feeding was started. This consisted of free access to finely ground oats to which an antibiotic-vitamin B_{12} supplement* had been added at the rate of 5 pounds per ton. In addition, the pigs had free access to skim milk during the creep feeding period. The pigs were weaned at 8 weeks and placed in individual pens measuring 5 feet x 10 feet. After weaning, the skim milk was fed at the rate of 1 to 1¼ pounds daily until the animals reached a live weight of 50 pounds. The pigs were fed the Canadian Advanced Registry feed mixtures. Dry feeding was practised and the pigs were fed individually in a self feeder. Water was supplied *ad libitum.*

Recording and Slaughter Procedure

Castration was always performed subsequent to the collection of the data on weight. Individual weights were taken at birth before the animals had sucked their dam and at weekly intervals until the age of 8 weeks. From 8 weeks until the time of slaughter, weights were taken every second week. The feed was kept in individual boxes for each pig and consumption was recorded at weighing time. When a pig reached the live weight of 205 ± 5 pounds, it was starved for a period of 24 hours before being slaughtered.

Carcass Grading and Sampling

Each carcass was weighed warm and allowed to chill for 48 hours in a cooler held at 34-38°F. When taken out of the cooler, the carcass was graded, measured, and scored as outlined under the National Bacon Hog Policy (13). A sample of fat, 3 inches x 2 inches, and 1½ inches deep, was removed from each carcass for iodine number determination. This sample was taken on the shoulder close to the median line and anterior to the third

*"Aurofac", supplied by Cyanamid of Canada Ltd., Toronto, Ont., is guaranteed to contain 1.8 gm. chlortetracycline and 1.8 mg. vitamin B_{12} per pound.

rib at the time the carcass was cut, wrapped in wax paper, and kept under refrigeration until analysed.

Statistical Analysis

The mean square for treatments was broken into a set of orthogonal comparisons (14). Since ages at castration were at unequal intervals, and since tabulated orthogonal polynomial coefficients are not available, necessary coefficients for this experiment were generated. A test of significance for the mean squares treatments x years, treatments x seasons, and treatments x years x seasons revealed no evidence of a significant interaction. Consequently, the three mean squares were pooled as an estimate of the error to test treatments.

Missing values were handled as described by Cochran and Cox (4). Unfortunately, in the third and fourth trials, 6 of the 8 pigs that were to be castrated at 20 weeks reached market weight before that age and were slaughtered. Even though castration was not performed, the data were collected and used for the statistical analysis in the same manner as if the treatment had been applied.

RESULTS AND DISCUSSION

Four trials were conducted to compare the effects of sex and age of male at castration. Only 3 pigs of the original 112 died, 2 in the first 2 weeks and 1 at 14 weeks, 2 weeks after castration. In addition, a boar became seriously ill at 18 weeks of age and had to be discarded. Beginning shortly after the age of 18 weeks, some pigs reached the market weight of 205 $\pm$ 5 pounds set forth in the experiment, and were slaughtered. Castration at 20 weeks was not practical because in this experiment, 7 of the 16 pigs allotted to that treatment attained market weight before that age. Because of the above mentioned fact, the information in the manuscript on growth, feed consumption, and carcass characteristics has little reliability for pigs being castrated at 20 weeks.

Live Weights and Gains

Comparative live weights at various age intervals are summarized in Table 1. The analysis of variance showed that the difference in birth

TABLE 1.—MEAN LIVE WEIGHTS OF PIGS AT VARIOUS AGE INTERVALS

	Cast. birth	Cast. 6 wk.	Cast. 12 wk.	Cast. 16 wk.	Cast. 20 wk.	Boar	Gilt
Number of pigs	16	16	16	16	16	16	16
Weight at birth, lb.	3.4	3.1	3.2	3.1	3.1	3.4	3.3
Weight at 6 wk., lb.	26.8	26.8[1]	27.4	27.6	27.4	27.8[1]	26.4
Weight at 12 wk., lb.	82.9	81.6[1]	80.4	81.2	80.7	82.2[1]	79.9
Weight at 16 wk., lb.	132.7	129.8[1]	129.5[1]	130.6	128.7	131.1[1]	126.2
Weight at 20 wk., lb.	180.7[3]	180.8[2]	180.8[4]	182.2[1]	176.1[3]	181.7[3]	169.9[3]

[1]15 pigs [2]14 pigs [3]13 pigs [4]12 pigs

TABLE 2.—EFFECTS OF SEX AND AGE OF CASTRATION ON GAINS AND FEED CONSUMPTION

	Cast. birth	Cast. 6 wk.	Cast. 12 wk.	Cast. 16 wk.	Cast. 20 wk.	Boar	Gilt
Number of pigs	16	15	15	16	9	14	16
Av. daily gain per pig:							
birth to market wt., lb.	1.35	1.34	1.34	1.34	1.34	1.34	1.32
weaning to market wt., lb.	1.77	1.74	1.74	1.74	1.75	1.73	1.71
Number of days on feed	92.3	94.0	94.2	93.1	94.1	93.4	97.8
Av. daily feed consumption, lb.	6.22	6.28	6.10	6.20	5.71	5.54	5.84
Feed per 100 lb. gain, lb.	353.2	360.5	354.2	355.7	328.2	319.4	343.8

weight between male and female pigs was not significant at the 5 per cent level. The difference between the heaviest lot of males and the gilts was only 0.14 pounds per pig. The difference in live weights between lots within weekly or bi-weekly intervals from birth to 18 weeks was rather small and was not significantly affected by sex or age of castration. The difference in live weight between males and females at the age of 20 weeks was only apparent owing to the fact that some pigs reached the requisite weight of 205 ± 5 pounds before that age and had to be slaughtered. Therefore, only the slowest gaining pigs remained at 20 weeks. The fast rate of growth of the pigs in this experiment might also explain why sex or age at castration did not show any effect.

The effect of castration on the gains made shortly after the operation was not apparent on birth castrates. Although not statistically significant, the gains made following castration at 6, 12, and 16 weeks were slightly affected, but eventually such animals caught up with the others 3 or 4 weeks after the operation. Information on daily gains (Table 2) indicates no significant difference between treatments. Similar results between boars, barrows, and gilts were obtained by Bratzler *et al.* (2).

Feed Requirement

The number of days the barrows and boars remained on feed ranged from 92.3 to 94.2 as against 97.8 for the gilts, but these differences failed to reach significance at the 5 per cent level. The feed requirement per 100 pounds of gain was less for boars than for barrows, and the gilts' requirement was intermediate between barrows and boars. These results agree with those of Wallace (15) who found that entire males were consistently outstanding in making economical gains and that there was only a slight difference between castrated males and unspayed females. Since the boars consumed less feed, and were on feed for practically the same length of time as the barrows, their average daily consumption was necessarily less. There was a highly significant difference in daily feed consumption between barrows. The sharp break after castration at 16 weeks (Figure 1) is noteworthy.

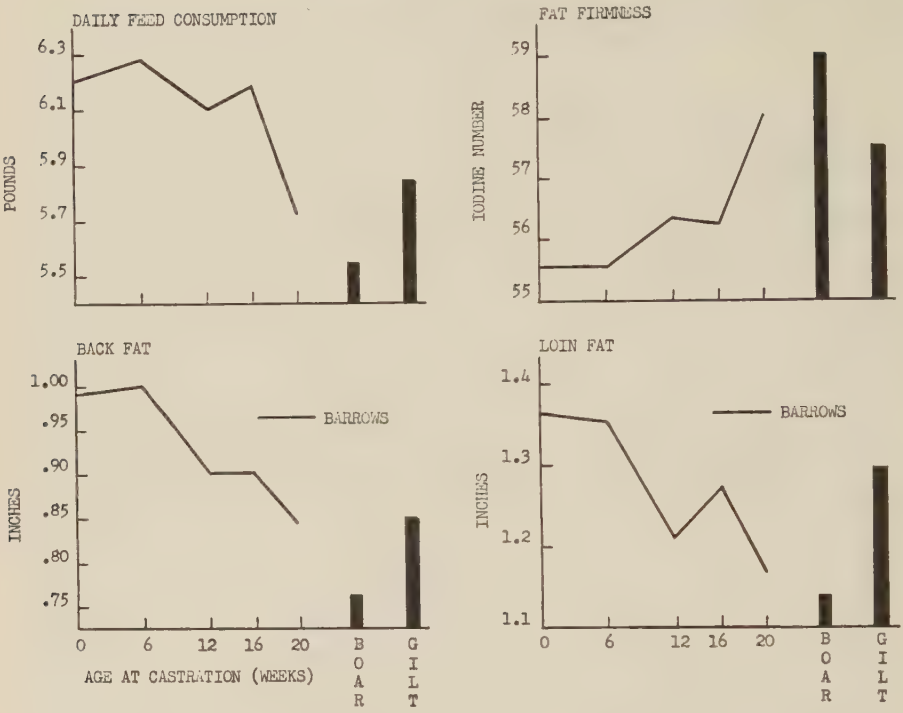

FIGURE 1. Feed consumption, fat firmness, and fat measurements of barrows, boars, and gilts.

Age at Slaughter and Shrinkage

The average age at which the experimental pigs were slaughtered was 151.1 days. As shown in Table 3, only the lot of females varied appreciably from this mean. They reached a live weight of 205 ± 5 pounds 3.7 to 5.6 days later than the various lots of male pigs. This was in agreement with the difference of 4.35 days between barrows and gilts reported by Bennett and Coles (1).

Sex and age of castration had no effect on the loss in weight during a 24-hour starving period prior to slaughter. The shrinkage from feed lot weight to slaughter weight was low, and the mean difference between any two lots did not exceed 1.3 percentage points.

Carcass Characteristics

The data presented in Table 3 and the analyses of variance in Tables 4 and 5 show rather conclusively that there was a considerable difference in a number of carcass characteristics of Yorkshire gilts, boars, and barrows castrated at various ages. The dressing percentage was calculated on carcasses chilled for 48 hours. There was no significant difference between boars, barrows, and gilts, but the significant linear component of regression on age at slaughter, as indicated in Table 4, suggests that dressing percentage decreased as the time of castration exceeded 6 weeks of age.

TABLE 3.—EFFECTS OF SEX AND AGE OF CASTRATION ON AGE AT SLAUGHTER, FEED LOT, STARVED, AND CARCASS WEIGHTS, SHRINKAGE, DRESSING PERCENTAGE AND CARCASS CHARACTERISTICS

	Cast. birth	Cast. 6 wk.	Cast. 12 wk.	Cast. 16 wk.	Cast. 20 wk.	Boar	Gilt
Number of pigs	16	15	15	16	9	14	16
Age at slaughter, days	149.3	151.0	151.2	150.0	151.1	150.4	154.9
Final feed lot weight, lb.	203.2	203.3	203.3	203.2	202.2	202.8	205.0
Starved weight, lb.	192.4	193.5	191.0	192.7	191.2	193.2	194.2
Per cent shrinkage	5.3	4.8	6.0	5.1	5.4	4.7	5.2
Cold carcass weight, lb.	154.4	157.0	152.7	153.8	150.6	152.9	154.9
Dressing percentage	80.2	81.1	80.0	79.8	78.8	79.1	79.8
Carcass length, in.	30.8	30.9	31.0	30.8	30.9	31.4	31.4
Thickness of:							
shoulder fat, in.	1.70	1.70	1.67	1.67	1.60	1.51	1.57
back fat, in.	0.99	1.00	0.90	0.90	0.84	0.76	0.85
loin fat, in.	1.37	1.36	1.21	1.27	1.17	1.14	1.30
Balance of side:							
per cent ham	23.7	23.1	23.8	23.8	24.0	23.9	24.1
per cent shoulder	27.5	27.0	27.6	27.2	27.9	28.2	27.1
per cent middle	48.7	49.9	48.6	48.9	48.1	47.9	48.8
Area of loin, in.	4.07	4.02	4.21	4.16	4.04	4.50	4.40
Total carcass score	74.1	68.0	80.2	76.0	79.3	76.4	81.0
Fat firmness, iodine no.	55.6	55.6	56.4	56.3	58.0	59.0	57.5

The information on the length of side shown in Table 3 indicated no difference between carcasses of boars and gilts. Age at castration had no effect on the length of side, but the barrows yielded shorter carcasses than the boars and gilts. The fact that carcasses of females were longer than those of barrows agrees with Bennett and Coles (1) and Fredeen (9).

The carcasses of boars were definitely leaner than those of barrows. The difference in shoulder and back fat thicknesses between boars and gilts was not significant, but it was for loin fat. In fat covering over the shoulder and back, the gilts were intermediate between the barrows and boars, but their fat covering over the loin was as thick as that of barrows. Carcasses of boars and gilts had less fat over the shoulder and back than barrows, but at the loin the difference was not statistically significant. The differences in shoulder fat thickness between the lots of barrows were small, indicating that age of castration had no effect. The linear effect of age of castration on fat thickness proved significant for back fat and loin fat, but castrates carried significantly greater fat at the shoulder and mid-back than did the sexually entire animals (Table 5).

The area of loin was greater in the carcasses of boars and gilts than in those of barrows. Differences in this trait favouring the gilts over the barrows support the findings of a number of investigators (1, 6, 9).

The iodine number determinations showed that the fat from most carcasses ranged from moderately firm to very firm. The barrows yielded a firmer fat than the boars and gilts and the pigs castrated early showed a lower iodine number than those castrated at 12 weeks or later. The iodine number of 1.9 in favour of the gilts over the barrows castrated at birth and

TABLE 4.—MEAN SQUARES FOR DAILY GAINS, DAYS ON FEED, FEED CONSUMPTION, SHRINKAGE, AGE AT SLAUGHTER, AND DRESSING PERCENTAGE

Source of variation	d.f.	Average daily gains			Number days on feed	Average daily feed consumption	Feed per 100 lb. gain	Per cent shrinkage in live weight	Age at slaughter	Dressing per cent
		Birth to weaning	Weaning to market weight	Birth to market weight						
Years	1	.3334	.0105	.0465	704.0	.032	41	78.05	705	1.46
Seasons	1	.0005	.0007	.0003	134.0	.469	1050	.13	135	2.52
Years x seasons	1	.0172	.2154	.0584	888.0	.151	13975	10.89	886	112.40
Blocks within seasons within years	24	.0199	.0352	.0144	213.8	.397	1518	1.79	214	5.10
Treatments	6	.0014	.0047	.0012	43.0	1.150**	3373*	2.59	45	7.80
Males vs. gilts	1	.0014	.0028	.0028	135.5	.630*	4167	1.82	142	3.05
Castrates vs. males + gilts	1	.0014	.0154	.0028	84.9	3.395**	7039*	2.64	88	5.96
Ages at castration	4	.0014	.0024	.0004	9.4	.718**	2258	2.76	10	9.45
Linear regression component	1	.0001	.0030	.0006	12.2	1.514**	3484	.54	15	20.98*
Quadratic regression component	1	.0000	.0003	.0004	.1	.798*	4275	.08	8	11.72
Remainder	2	.0028	.0034	.0002	12.7	.281	637	5.22	8	2.56
Treatments x years	6	.0116	.0302	.0143	129.7	.208	1586	1.61	130	3.45
Treatments x seasons — error	6	.0074	.0212	.0079	161.2	.155	1183	1.38	161	6.52
Treatments x years x seasons	6	.0044	.0186	.0079	85.3	.063	700	1.53	85	2.67
Intra-block error	50	.0069	.0184	.0061	82.6	.115	699	2.14	83	1.50

*Significant at P = 0.05
**Significant at P = 0.01

TABLE 5.—MEAN SQUARES FOR CARCASS MEASUREMENTS, SCORE, AND IODINE NUMBER

Source of variation	d.f.	Length	Thickness of backfat			Balance of side			Loin area	Carcass score	Iodine number
			Shoulder	Back	Loin	Ham	Shoulder	Middle			
Years	1	.69	.009	.003	.056	.18	32.78	37.84	.498	2	1.1
Seasons	1	3.09	.630	.023	.354	4.60	27.20	9.43	3.771	287	124.5
Years x seasons	1	1.85	.070	.013	.007	.03	6.71	5.90	.057	272	7.6
Blocks within seasons within years	24	2.08	.055	.035	.049	1.04	1.88	3.39	.491	310	8.3
Treatments	6	.87	.074	.101*	.114**	1.48	2.71*	5.83*	.481	280	23.3**
Males vs. gilts	1	.04	.025	.057	.179*	.28	8.47**	5.67	.070	148	15.8
Castrates vs. males + gilts	1	4.80**	.328*	.291**	.062	2.05	.88	4.80	2.380**	202	69.5**
Ages at castration	4	.10	.023	.064	.442**	1.64	1.72	6.13*	.093	332*	13.6*
Linear regression component	1	.07	.068	.222*	.347**	.58	.01	5.94	.012	493*	38.2**
Quadratic regression component	1	.13	.017	.000	.001	1.55	2.36	8.51	.001	47	10.2
Remainder	2	.09	.042	.035	.047	2.21	2.26	5.04	.180	395*	3.0
Treatments x years	6	.76	.046	.013	.024	.80	.53	.38	.406	56	4.4
Treatments x seasons — error	6	.18	.019	.028	.028	1.16	1.06	3.42	.154	97	3.0
Treatments x years x seasons	6	.50	.059	.045	.018	.92	.62	2.28	.213	165	4.0
Intra-block error	50	.32	.024	.014	.014	.57	.68	1.50	.230	100	3.0

*Significant at P = 0.05
**Significant at P = 0.01

6 weeks agreed with that of 1.7 found by Lush *et al.* (12). Keeping in mind that the fats were all of a firmness well accepted by the meat industry, the date of castration in this experiment should not be considered an important factor in regard to fat quality. The pigs on this experiment were fed a ration containing 46 per cent barley during the fattening period, and this feed has a tendency to produce hard fat because of its low fat content. However, if a feed that had a tendency to produce soft pork were introduced, then carcasses from boars, gilts, and barrows castrated late in life might present some difficulties.

Information on the balance of side is given in Table 3. There was no statistical difference between carcasses of boars, gilts, and barrows in per cent of ham, but some difference was indicated in shoulder and middle. The boars yielded a heavier percentage of shoulder than the gilts and barrows, but no difference between females and castrated males was observed. The percentage of middle was affected by the age at castration. The low carcass score obtained by the barrows castrated at 6 weeks was caused by the low scoring of a few carcasses in this lot.

A slice of pork from a ham of each carcass was cooked in a frying-pan for acceptability tests. Meat produced by boars was of very acceptable quality with no sexual odour. This was in agreement with Wallace (15). However, it was contrary to results where boars produced pork that had a definite "off" flavour and odour (2). The pigs in that experiment were of a different breed and were slaughtered at 209 days at a weight of 210-230 pounds, while the ones reported here were slaughtered at 205 ± 5 pounds at an average age of 151 days. While the commercial meat trade would question the suitability of boar carcasses there would seem to be a need for further studies on the necessity of castration in swine, especially with pigs that reach market weight at approximately 150 days of age. The discrimination of the market where the animals are sold would determine whether or not it was economical to castrate boars. At present, uncastrated males are not wanted and it is not suggested that the commercial producers should raise such pigs to a weight of 200 pounds since the net returns per pig would be greatly affected. It is still necessary to castrate the boars intended for bacon production, although the operation can take place as late as 3 or 4 weeks before slaughter. However, pigs sold at a live weight of 150-160 pounds for fresh pork could be slaughtered without being castrated if they were disposed of on a market where there was no discrimination in price. Delaying castration until 3 or 4 weeks before slaughter is a great advantage to the breeder of registered swine since growth, physical carcass characteristics or feed requirements will not be seriously affected in the pigs not selected as boars.

Although boars have heavy shoulders and light ham and middle, their superiority of feed efficiency, length of carcass, thinness of fat and area of loin are worth consideration from the producer's point of view. To the consumer who demands lean pork, carcasses of boars would seem to show a great advantage. However, recommending a policy of non-castration might prove difficult since the producers will need to realize that age and weight

are two important factors in determining when pigs should be sold as barrows or boars.

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ESTIMATING BREEDING VALUES OF DAIRY BULLS FROM CANADIAN R.O.P. RECORDS[1]

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ABSTRACT

A random assortment of mates is implicit in published methods for estimating breeding value of dairy sires, based on daughter-dam or daughter-contemporary comparisons. A combination of the two methods, based on first lactation records of dams and daughters and of their own contemporaries, is proposed and will be tested when sufficient data are available. A method based on a maximum likelihood estimate of contemporaries was used to analyse data available from Canadian Record of Performance for four breeds with an estimated 40 to 470 testable bulls biannually. Some 50 per cent of the herds were considered too small to provide suitable records. Breeding values of sires were over- or underestimated from simple averages of progeny and this bias was reduced by using contemporaries. The handicap to younger sires, resulting from the correlation between contemporary comparisons and average age of progeny groups, can be avoided by making the comparisons within age groups.

INTRODUCTION

The purpose of this paper is to present quantitative principles of estimating breeding values in algebraic and biological terms, and to point out practical difficulties that arise in application to existing breeding records. Theoretical considerations of several methods are discussed in this introduction. One of the better methods is then applied to data available from Canadian Record of Performance (R.O.P.) records.

Economic traits, such as milk yield, are quantitative and are expressed through complicated actions and interactions of many genes and environmental factors. Present concepts call for averages of well-defined populations or sub-populations as the base of the measuring scale. Deviations from these averages are caused by both genetic and environmental factors. In its simplest terms, $Y - P = G + E$ illustrates the concept that the deviation of record Y from population mean P equals the genetic component G plus the environmental component E. Components G and E may be positive or negative, but added together they determine the superiority or inferiority of performance as measured from a population average.

The assumptions underlying this simple concept may not always be acceptable. Regardless of the type of gene action or interactions responsible for G, however, and of possible interactions between G and E, one fact is clear. About 70 per cent of the total variation in milk production is environmental in origin (5), and testing programs must be designed to minimize E.

The comparison of daughters with dams was probably the first method used in organized milk-testing schemes (8), and was based on the theory that a superior sire should beget daughters that will out-produce their dams. But daughters and dams are unlikely to be in production at the same time, so that a valid estimate of E is not obtained.

[1]Contribution No. 50, Animal Research Institute, Research Branch, Ottawa, Ont.

The U.K. Milk Marketing Board (7) uses contemporary stablemates to compare with a sire's progeny. These contemporaries are in production during the same year-season. Age-correction factors must be applied. Provided there has been no choice of mates of sires used in a herd, differences arising from the genetic influence of dams and from environmental factors are minimized. Hence it is possible to estimate the genotypic effect of the sire being evaluated in comparison with the mean effect of the other bulls.

Henderson *et al.* (4) based their method on a maximum likelihood estimate of contemporaries. For single records per head the formula is

$$Y_1 - 0.9\left[\frac{n_2(Y_2 - Y_m)}{n_2 + 1}\right]$$

where Y_1 = production of a daughter whose sire is being evaluated
Y_2 = average production of n_2 contemporaries
Y_m = population average.

The factor 0.9 is derived from the intra-sire regression found by Robertson (10) and Henderson *et al.* (4) for daughter performance on contemporary herd performance. The Robertson and Henderson methods are similarly designed to remove the inter-herd source of variance from progeny comparisons.

Cartwright *et al.* (3) divided individual performance, Y_1, by the herd average performance H. This introduces two disadvantages. If the ratio Y_1/H be identified as R, the variance of $R = 1/H^2\ (\sigma_Y^2 + R^2\sigma_H^4 - 2R\sigma_H^2)$; in adjusting for disproportionate variances among herds, this leads to more data-processing problems than does the deviation from H. Furthermore, R is not evaluated in units of yield and cannot be interpreted monetarily or genetically in the most meaningful terms.

The assumption underlying methods discussed so far is that the sires being evaluated are mated at random so that, on the average, all groups of mates are of the same breeding value. This occurs in many commercial non-purebred herds where the choice of the donor bull is left to the A.I. technician. But the assumption is not valid where planned mating is practised: in purebred herds and, with the present availability of frozen semen, in an increasing number of non-purebred commercial herds.

Adjustment for differences among mates must be investigated for its effect on accuracy of progeny tests. The most direct method is to calculate the deviation of all first-lactation records of daughters and of dams from the average production of their respective contemporaries. Deviations can be sorted by sire and combined by daughter and dam to evaluate various progeny groups on the basis of the formula

$$(Y_1 - Y_2) - h/2(Y_1^d - Y_2^d) \quad [1]$$

where h = heritability of single records
Y_1^d = production of the dam
Y_2^d = average production of dam's contemporaries
Y_1 and Y_2 are the same as in Henderson's formula.

The variance can be stabilized among herds of different sizes by the method described by Robertson *et al.* (11). Data for this investigation of adjustment for differences among mates are being accumulated in a national dairy cattle breeding project, and will be reported at a later date.

The remainder of this paper describes the application of a modification of the method of Henderson *et al.* (loc. cit.) to data available from Canadian R.O.P. records.

EXPERIMENTAL METHODS

The Canadian Record of Performance (2) milk records collected in 1956 for all breeds were surveyed to determine their suitability for comparisons with contemporaries. It was considered that at least 1000 records were necessary to justify the analysis and that these should be from herds with at least 10 records per herd-season. Similarly, for fewer than 1000 records, the cost of routine analyses in terms of the possible genetic improvement would be unwarranted, and without at least 10 records per herd-season the herd averages would be too unreliable to give suitable measures of herd environment. As a check on the suitability of the minimum herd size of 10, the percentages of one-sire herds in herds with 10 records of more and of those with less than 10 were calculated.

Early examination of the data revealed that Equation 1 could not be applied because prior to 1956 the herds to which cattle belonged were not recorded under the R.O.P. scheme. Therefore, deviation of daughters' production from the average production of contemporaries could be obtained, but records on the dams could not be sorted by herd and an average for dam contemporaries could not be calculated. Study of the importance of correcting for a possible non-random allotment of mates among sires by application of Equation 1 must await several years' operation of the present R.O.P. scheme in order to have averages for contemporaries of dams.

All the records used for analysis were previously corrected for age at freshening using the Breed Class Average method as described in the Canadian R.O.P. (2). This produces an age-corrected yield measurement that ideally averages 100.

The equation used in analysing the data was as follows:

Breeding value of sire

$$\sum_{\text{over herds}} \left(\frac{\Sigma Y_1 - \dfrac{.9n_1(n_2Y_2 - n_2Y_m)}{n_2 + 1}}{Y_m} - n_1 \right) \left(\frac{100}{\Sigma n_1 + 10} \right) + 100 \quad \ldots\ldots\ldots\ldots [2]$$

The Y's and n_2 were defined previously and n_1 is the number of daughter records of a given sire in any single herd.

The records for September through February (Season 1) and for March through August (Season 2) were analysed separately because the Y_m's for these periods account for a major portion of the seasonal variation in milk yield (5). Evaluating progeny records without regard to seasonal variation introduces biases when bulls are not represented by equal numbers

of daughters in different seasons. The results of applying Equation 2 to the Holstein data, which were the most numerous for a single breed, were compared with the results of calculating simple averages of daughter production per bull. These averages ignore the confounding effect of herd environment on progeny tests. Yet the effect of this confounding should become less as the number of herds per progeny group increases. Hence the comparison was made separately for large and small progeny groups.

The records analysed represented several year-seasons and animals of all ages. Because of this the older sires may possibly have been represented by progeny older than average. This would allow the older sires to be represented by the most highly selected and thus the higher-producing cows of the population. Also with a variation in age among sire progeny, the possible biases associated with age correction procedures (6) may prejudice the young or old sires, depending on the nature of the bias. The comparisons with contemporaries on data from all breeds were, therefore, plotted by age of progeny group in order to examine trends.

Considerations were given to estimates of how many bulls could be accurately evaluated from the volume of records now being reported. The possible rate of genetic improvement in milk yield from using comparisons with contemporaries for selecting sires was also estimated.

RESULTS

Table 1 gives the number of records by breed and year-season that were available at the time of analysis. For the breeds with more year-season records than the required 1000 the numbers of herds represented are given. Four of the eight breeds represented have large enough numbers to justify analysis of sires by comparison of daughters with contemporaries.

Table 2 shows, for the records used, the percentages of records for the various breeds and year-seasons that totalled 10 or more per herd in 6 months and the percentages of herds for which there were 10 or more records. Although all the latter percentages were low, the former were

TABLE 1.—NUMBERS OF RECORDS BY YEAR-SEASON AND BREED FOR ALL R.O.P. HERDS, 1953-1956

Breed	'53-2[2]	'53-1	'54-2	'54-1	'55-2	'55-1	'56-2	Total
Shorthorn				15	188	321	74	598
Brown Swiss					4	15	1	20
Red Poll				5	71	83	20	179
Canadian				7	292	262	182	743
Guernsey				50	740	1289[1] (192)	181	2260
Jersey	2	1		103	1631 (361)	3073 (363)	554	5464
Ayrshire	3	3		88	2032 (510)	3077 (483)	737	5940
Holstein		4		310	7214 (1968)	13291 (2122)	2321	23155

[1]Number of herds in parentheses
[2]Season 1, September through February; season 2, March through August

TABLE 2.—PERCENTAGES OF HERDS, AND OF RECORDS OF HERDS, WITH 10 OR MORE RECORDS THAT WERE STARTED IN YEAR-SEASONS OF 1,000 OR MORE RECORDS

Breed	Year-season record started	Total no. records	No. herds with 10 or more records	Percentage of records in herds with 10 or more records	Percentage of herds with 10 or more records
Holstein	1955 (2)[1]	2,967	360	41.1	18.3
	1955 (1)	10,050	1046	75.6	49.3
	1956 (2)	250	35	10.8	3.0
Ayrshire	1955 (2)	935	113	46.0	22.2
	1955 (1)	2,313	215	75.2	44.5
Jersey	1955 (2)	958	99	58.7	27.4
	1955 (1)	2,659	215	86.5	59.2
Guernsey	1955 (1)	1,053	104	81.7	54.2

[1]Season 1, September through February; season 2, March through August

much higher. Thus the frequency distribution of herd size was skewed and there were proportionately many more records for the large herds than for the small ones. If a higher limit were set on minimum herd size for entry into the R.O.P. program, the percentage increase of usable records would be greater than the percentage of herds eliminated; the percentage of one-sire herds in the herds included in the analysis was 0.4; in the remainder, 35.5. Since progeny of another sire are required for comparisons with contemporaries, elimination of the small herds would detract very little of importance from a sire evaluation analysis.

Figure 1 illustrates the relative precision of simple averages for sire evaluation on variation for large and for small progeny groups. For only the progeny groups of 35 or more records the average of the records bore essentially a 1:1 relation to the values obtained by comparisons with contemporaries. Therefore, the use of averages over- or under-estimates breeding value of sires when progeny groups are small.

The relation between the age of the progeny group and the breeding value of the sire obtained by comparison of contemporaries is shown in Figure 2 for all breeds. Although there was wide variation in the breeding value with increase in age of the progeny group, the obvious over-all increase from the young to the old was significant for each breed. This increase was in the direction expected because of the more highly selected animals comprising the older progeny groups. The exact cause of this trend could not be isolated with the data at hand.

The over-all standard deviation of breeding values as estimated from the comparison with contemporaries was 3.8. With this and knowledge of the average number of progeny per bull, the expected annual genetic gain in milk production from culling 50 per cent of all bulls tested each 6-month period was calculated. The correlation between the actual breeding value and the estimated breeding value multiplied by the number of standard deviations the 50 per cent selected bulls would be above the population average, is 0.798. This multiplied by the estimated standard deviation

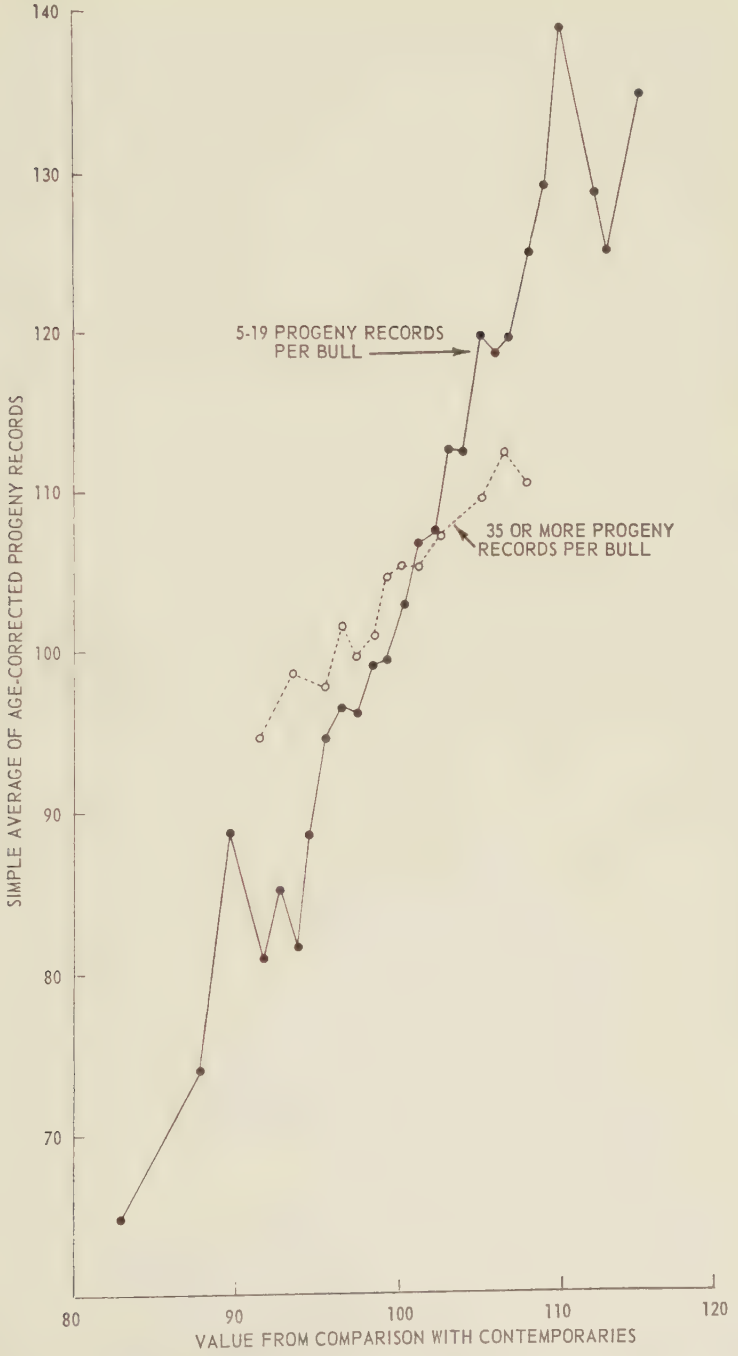

FIGURE 1. Precision of evaluation of sires by means of production averages of small and of large progeny groups.

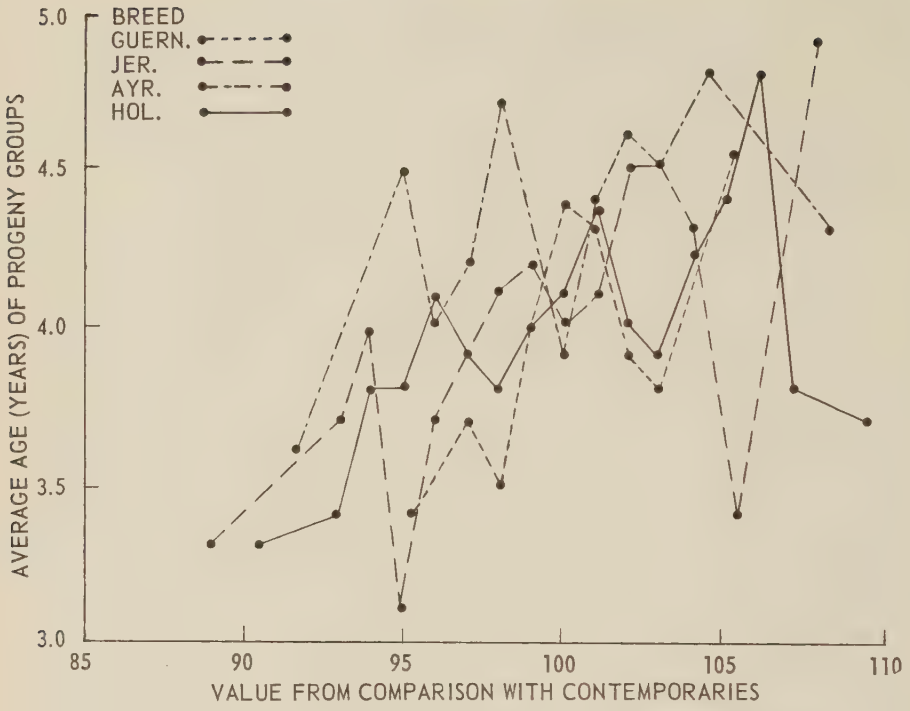

FIGURE 2. Average age of progeny groups in relation to estimated breeding values of sires.

of 3.8 and divided by the average age of the bulls gives 0.379, which is an estimate of annual genetic gain. Since the age-correction procedure used is expected to give an average production of 100 for the population, the 0.379 is percentage gain. Milk production is approximately 10,000 pounds per lactation for Holsteins, so that the genetic gain would be approximately 37.9 pounds of milk per year.

The number of bulls that could be evaluated biannually on the basis of the present data is 40 Guernseys, 160 Jerseys, 150 Ayrshires and 470 Holsteins. Half of these would have to be culled biannually and replaced with younger bulls of higher transmitting ability in order to attain the estimated genetic gain.

DISCUSSION

Mechanical means are necessary for efficient analysis of the great volumes of data in programs such as the R.O.P. Ordinary punched-card equipment was found suitable for the work performed in this study. Such machines are considered suitable for routine use in various sizes of programs as the difficulty of processing is essentially independent of amounts of data. The Canadian R.O.P. records are conveniently available on punched cards, which were used in issuing production certificates for individual cows.

Recent changes in this program eliminated the spread in years of freshening (Table 1) for records reported during one year. This makes a higher percentage of suitable records and thus the estimated number of bulls tested that can be reported annually is considered a minimum.

It is highly unlikely that these or other changes that affect the operation of the program will eliminate the factor or factors causing the relationship between age of progeny group and estimate of breeding value obtained by comparison with contemporaries. Whether errors in age-correction factors are responsible or to what extent these and selection are involved cannot be determined with these data. Without further knowledge of this relationship and ways to eliminate it the comparison with contemporary analysis should be applied within age groups of sire progeny. Otherwise, the older bulls, being represented by older than average daughters, will be unfairly evaluated as better than the younger bulls and replacement rate of bulls will be decreased.

The amount of sire selection for yield that is being practised in Canada is not known. Estimates of possible genetic improvement in this paper are based on a 50 per cent culling of tested bulls. Becker and Arnold (1) report that approximately 50 per cent of the bulls used in artificial service are culled for low reproduction performance, disease, accidents, etc. To cull an additional 50 per cent on results of progeny tests would require testing of four times the number remaining. Robertson and Rendel (9) calculate that the optimum number of bulls to be culled on progeny test information is 95 per cent so that for maximum improvement at least 20 times the number of selected bulls required should be tested. It is highly unlikely that any artificial insemination unit is practising such a program to provide maximum genetic gain. The high cost of testing large numbers of bulls is the major factor and is a problem of equal importance to that of establishing a high percentage of milk-recorded herds.

Records are needed on proportionately more animals of the less popular breeds than of the other breeds if a given degree of genetic improvement is to be attained. A relationship exists between rate of genetic improvement and size of population. Robertson and Rendel (9) indicate that, over a wide range of number of selected bulls required, optimum number of females is approximately 1500. Steele (13) estimates that only 5.6 per cent of all milk cows in Canada are milk-tested. This testing is a benefit to those not testing through production information on prospective replacements of breeding stock. With knowledge that genetic gain increases with the number of animals tested there should be a greater sharing of the costs of milk-testing by enlisting a larger number of herds.

The production records that become available for sire analysis should be used for maximum genetic gain. There is considerably more work to using comparisons with contemporaries than to using simple averages but the latter are misleading with small numbers. Since it is important to evaluate sires as early as possible the smaller the number of progeny for a given accuracy the greater the rate of gain. Unfortunately, the minimum number per progeny group for a given accuracy cannot be stated for every

case (12). The number required is conditioned by the nature of the particular testing program and on the accuracy of the particular method used for evaluating the progeny records. The more accurate the method the fewer the animals required. As R.O.P. records accumulate with herd identification, the possibility of improving accuracy by correcting for non-random assortment of mates should be investigated.

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SILICA UROLITHIASIS IN BEEF CATTLE.

IV. THE RELATIONSHIP BETWEEN THE pH AND BUFFERING CAPACITY OF THE ASH OF CERTAIN FEEDS, pH OF THE URINE, AND UROLITHIASIS[1]

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ABSTRACT

Two experiments were carried out to determine the relationship existing between the pH and buffering capacity of the ash of feeds and the urine pH, and the incidence of silica urolithiasis.

In the first experiment the pH and buffering capacity were determined on the ash of 51 feeds of plant origin. No statistical relationship between the pH of the ash and its buffering capacity was found. Twenty-one of these feeds and four chemical compounds were fed to Holstein steer calves and the urine pH recorded. Twelve of the twenty-one feeds produced an acid urine.

In the second experiment, four Holstein steer calves were fed for 6 months on rations designed to produce either an acid or alkaline urine. All calves produced silicerous urinary calculi. Urine pH *per se* did not seem to be a factor in the incidence of silica urolithiasis.

INTRODUCTION

Urolithiasis, urinary calculi, kidney stones, bladder stones, and water belly, although not exactly synonymous terms, are often used interchangeably to describe the same disease of cattle which is a serious problem in southern Alberta, southern Saskatchewan, and northern Montana (3). The calculi, which are composed mainly of silica (6), form in the kidney and/or bladder and frequently become sufficiently large to block the urethra. In such instances pressure of the urine ruptures the bladder (water belly), which usually results in the death of the animal.

Several theories have been advanced concerning the etiology of urolithiasis. Puntriano (11) found that urine from healthy animals contained protective colloids, which may prevent the formation of uroliths. When the level of protective colloids is inadequate, calculi may form. The presence of protein in most calculi has suggested to some workers that it might be involved in this problem. Keeler and Swingle (10), Udall (13), and Udall *et al.* (14) suggested that urinary mucoproteins may cause the precipitation of silica molecules to form uroliths. Bauman (2) stated that the reverse procedure takes place, namely that polysilicic acid possesses the power to precipitate proteins. Swingle (12) contended that, although alkalis tend to form soluble silicates and acids will precipitate silicic acid, these effects would not be encountered in the pH range of urine. Holt and Yates (7) found that polymerization of silicic acid was very rapid at pH 5.5 to 6.0, but even at pH 7.4 the formation of polysilicic acid was possible, if the silicic acid concentration was high enough. Hurd and Sheffer (8) reported that, when other factors were constant, the time required for polymerization of silicic acid was proportional to the pH and inversely proportional to the square of the silica concentration. Iler (9) found that very little silica was present in solution in the form of silicate ions below about pH 9.

[1]Contribution from the Animal Science Section, Research Station, Canada Department of Agriculture, Lethbridge, Alta.

TABLE 1. — THE pH AND BUFFERING CAPACITY OF THE ASH OF SOME PLANT MATERIAL

Item no.		pH of ash	Buffering capacity (M_1 acid to pH 5.0)
	Green needlegrass, *Stipa viridula*		
1	Stage 1[1]	11.4	25
2	2	11.7	86
3	3	11.6	71
4	4	11.2	32
5	5	9.7	20
	Timothy, *Phleum pratense*		
6	Stage 1	11.7	92
7	2	11.8	88
8	3	11.2	23
9	4	11.1	40
10	5	10.6	23
	Idaho fescue, *Festuca idahoensis*		
11	Stage 1	11.5	29
12	2	11.2	16
13	3	11.4	34
14	4	10.7	25
15	5	10.0	23
	Northern awnless brome, *Bromus pumpellianus*		
16	Stage 1	11.9	135
17	2	11.9	119
18	3	11.6	138
19	4	11.0	36
20	5	11.0	42
	Parry's oatgrass, *Danthonia parryi*		
21	Stage 1	11.2	33
22	2	11.3	43
23	3	10.9	32
24	4	10.9	36
25	5	10.2	29
	Rough fescue, *Festuca scabrella*		
26	Stage 1	11.5	34
27	2	11.5	41
28	3	11.5	43
29	4	10.7	22
30	5	10.0	25
31	Rough fescue hay from southeastern Alberta	9.5	8
32	Rough fescue hay from Research Station, Lethbridge	9.8	16
33	Rough fescue hay from 30 miles south of Lethbridge	10.5	15
34	Rough fescue hay from southwestern Alberta (foothills)	10.6	12
35	Blue grama grass hay, *Boutelous gracilis*	10.4	13
36	June grass hay, *Koeleria cristata*	10.8	21
37	Alfalfa hay, *Medicago sativa*	10.6	84
38	Brome grass hay, *Bromus inermis*	10.9	44
39	Crested wheatgrass hay, *Agropyron cristatum*	11.5	64
40	Russian wild rye hay, *Elymus junceus*	11.5	103
41	Speargrass hay, *Stipa comata*	10.0	14
42	Wheat straw	11.3	64
43	Molasses-beet pulp (dried beet pulp+30% molasses)	10.3	23
44	Rice hulls (23 per cent silica)	5.2	1 drop
45	Barley	9.1	12
46	Oats	9.5	17
47	Wheat	7.1	2

TABLE 1 (*continued*)

Item no.		pH of ash	Buffering capacity (M_1 acid to pH 5.0)
48	Wheat bran	8.7	13
49	Linseed meal	11.1	86
50	Rapeseed meal	9.7	19
51	Soybean meal	10.4	94

[1]Stage 1. *Leaf stage* — samples were obtained between the initiation of spring growth and before the appearance of seed heads
" 2. *Heading* — after the appearance of seed heads but prior to the ripening of the seeds
" 3. *Seed ripe* — after ripening of the seed and up to shattering of the seed head
" 4. *Cured* — after cessation of active growth
" 5. *After winter exposure* — samples obtained in early spring before the initiation of spring growth

Forman *et al.* (5) reported that, when red clover hay was fed to sheep, they produced urine with a pH of 8.2, which is considered normal for ruminants (1, 4). However, when they fed native prairie hay consisting mainly of speargrass, *Stipa comata*, the urine pH dropped to 5.5. In previous work at this Station, it was found that, when native hay was fed to wethers and steers, they consistently produced an acid urine having pH values as low as 5.0. From this review of the literature it would seem to be well within the realm of possibility that soluble silicates in the urine might be precipitated as a polysilicic acid. The fact that native prairie hay contains large amounts of silica [Forman (5) found 8.28 per cent in their western hay] increases the possibility of polymerization of silica in the kidneys and bladders of these animals. This study was carried out using the ruminant animal to measure the differences in the pH and buffering capacity of several species of plants and their effect on urine pH.

METHODS AND MATERIALS

Experiment 1

The pH and buffering capacity of the ash of six grass species harvested at five stages of maturity, molasses-beet pulp, rice hulls, and a number of hays, oilseed meals, and cereal grains were determined by the following method. A quantity of the feed was ashed; 1 gram of the ash was placed in a 250-millilitre beaker and mixed with 50 millilitres of distilled water. The pH of this mixture was determined on an automatic titrator and then titrated with 0.1N H_2SO_4 to pH 5.0. pH5 was chosen because the ashes of the feed under test exhibited very little or no buffering action below this level and, in addition, any buffering effect below pH 5 would be of no benefit to the biological system. The quantity of standard acid used was recorded as the buffering capacity. A total of 51 feeds was studied.

Twenty-one of these feeds that were available in sufficient quantities for a feeding trial and four chemical compounds (monopotassium phosphate, magnesium carbonate, sodium bicarbonate, and potassium bicarbonate) were fed to Holstein steer calves in order to observe their effect on urine pH. The calves were started at 1 week of age and were used intermittently up

to 1½ years of age. Urine samples, for pH determinations, were taken daily at 8.30 a.m. except Saturdays and Sundays, by means of a rubber funnel and polyethylene bottle strapped on the animal and the pH determined within a half-hour. Each feed was fed for at least 1 week or until the urine pH became stabilized. Water was before them at all times.

Experiment 2

In order to learn if alkaline urine prevents the formation of silica calculi, two 7-day-old Holstein steer calves were fed a ration that was known to result in an acid urine and two were fed the same ration, but to which was added sufficient potassium bicarbonate (mixed in the milk) to result in an alkaline urine. Water was fed *ad libitum* to both groups. It was found from previous work that Holstein calves did not normally have urinary calculi. The daily ration was composed of 10 pounds of milk, plus native hay (predominantly rough fescue, *Festuca scabrella*) *ad libitum*. At 6 months of age the calves were slaughtered and the kidneys and bladders examined for calculi.

RESULTS AND DISCUSSION

Experiment 1

The ashes of the six species of grass that were collected at five stages of growth (Table 1) showed a definite lowering of pH after maturity and winter exposure and, in general, the buffering capacity followed the same trend. Because rough fescue is the predominant grass in some of the affected areas in southern Alberta and may be implicated in the problem of silica urolithiasis, samples of this forage were taken from several areas. In all cases its ash exhibited a relatively low buffering capacity as did the ash of three other native species, blue grama grass, *Boutelua gracilis*, June grass, *Koeleria cristata*, and speargrass, *Stipa comata*. The ash of the other roughages (items 37, 38, 39, 40, and 42, Table 1) possessed a greater buffering capacity.

The rice hulls were peculiar in that the silica content was very high (23 per cent), while the pH of the ash and its buffering capacity were very low. Theoretically it would make an ideal feed for producing silica uroliths but, unfortunately, it lacks palatability. The ashes of the three cereal grains and bran (items 45 to 48) had a buffering capacity about equal to the native grasses, whereas the two protein concentrates (linseed meal, item 49, and soybean meal, item 51) exhibited a relatively high buffering capacity. Rapeseed meal ash possessed buffering properties midway between these groups.

Although the ashes with a high buffering capacity (i.e., items 16, 17, 18, and 40, Table 1) had a high pH and rice hulls with the lowest pH had the lowest buffering capacity, the ashes in between the two extremes showed no consistent relationship between pH and buffering capacity.

The data reported in Table 2 are the averages of at least two different animals. More than half of the rations (12 out of 21), when fed to calves, resulted in acid urines. This is interesting in view of the fact that most reports state that the normal pH of cattle urine is 8.0 or over.

TABLE 2. — THE pH OF THE URINE OF CALVES FED SOME COMMON FEEDS

Ration no.		Urine pH
1	Whole milk *ad lib.* (2-day-old calves)	6.7
2	Native hay[1] *ad lib.*+10 lb. milk	6.0
3	Alfalfa hay (Item 37)[2] *ad lib.* + 10 lb. milk	8.2
4	Pasture[3] *ad lib.*	8.3
5	Pasture[4] *ad lib.*	5.8
6	Alfalfa hay (Item 37) *ad lib.*	8.4
7	Crested wheat grass hay (Item 39) *ad lib.*	8.0
8	Russian wild rye hay (Item 40) *ad lib.*	7.9
9	Barley (Item 45), 15 lb. (max.)[5]	6.0
10	Native hay *ad lib.*	6.0
11	Native hay *ad lib.*+ 2 lb. beet molasses (max.)	8.3
12	Native hay *ad lib.*+ 6 lb. molasses-beet pulp[6] (max.) (Item 43)	8.3
13	Native hay *ad lib.*+ 1 lb. rice hulls (Item 44) (max.)	6.9
14	Native hay *ad lib.*+ 8 lb. barley (Item 45) (max.)	6.5
15	Native hay *ad lib.*+ 4 lb. oats (Item 46) (max.)	6.5
16	Native hay *ad lib.*+ 6 lb. wheat (Item 47) (max.)	6.8
17	Native hay *ad lib.*+ 4 lb. wheat bran (Item 48) (max.)	7.2
18	Native hay *ad lib.*+ 4 lb. commercial calf pellets (25% protein)	6.3
19	Native hay *ad lib.*+12 lb. linseed meal (Item 49) (max.)	5.9
20	Native hay *ad lib.*+ 4 lb. rapeseed meal (Item 50) (max.)	6.8
21	Native hay *ad lib.*+10 lb. soybean meal (Item 51) (max.)	8.3
22	Native hay *ad lib.*+20 gm. KH_2PO_4	6.8
23	Native hay *ad lib.*+30 gm. $MgCO_3$	6.4
24	Native hay *ad lib.*+30 gm. $NaHCO_3$	7.7
25	Native hay *ad lib.*+30 gm. $KHCO_3$	8.3

[1]The native hay used in all rations was predominantly rough fescue and was the same as Item 31, Table 1
[2]Item numbers in brackets refer to the same feed as shown in Table 1
[3]Predominantly speargrass
[4]Predominantly rough fescue
[5]The feeds marked (max.) indicate that this was the maximum quantity the animals would consume without going off feed
[6]Molasses-beet pulp is dried beet pulp in which has been incorporated 30 per cent beet molasses

The urine pH resulting from any feed depends in part on the ratio of acid to base forming components which it contains. This is probably the reason why the pH of the urine produced when high protein feeds, such as linseed meal and rapeseed meal, were fed was more acid (Table 2) than might be expected from the buffering capacity of the ash (Table 1). Russian wild rye, *Elymus junceus* (Table 1, item 40, and Table 2, ration 8) is a relatively new and promising forage in southern Alberta. It withstands drought well, contains appreciable quantities of protein, and provides excellent fall and winter pasture.

As one might expect, the potassium acid phosphate when fed resulted in an acid urine. However, the magnesium carbonate brought about a similar condition, but this may be accounted for by the fact that, at this level of intake (30 grams per day), the animals scoured severely. Although sodium and potassium bicarbonate, when fed, caused the urine to become alkaline, the latter resulted in an alkaline urine in less time and at a lower intake.

Experiment 2

At the outset the two calves receiving potassium bicarbonate produced an alkaline urine with a daily intake of 15 grams. The quantity was in-

creased by 5 grams each time the urine pH went below 7.5. During the last 2 months they were each receiving 50 grams of potassium bicarbonate per day.

The bladders of all four calves contained siliceous calculi but none was found in the kidneys. The fact that calculi were present indicates that factors other than acid urine *per se* are involved in the formation of siliceous urinary calculi.

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PASTURE FOR YOUNG DAIRY STOCK

I. EFFECT OF PREVIOUS NUTRITIONAL LEVEL AND AGE ON GROWTH OF AYRSHIRE AND HOLSTEIN HEIFER CALVES AND YEARLINGS ON PASTURE[1]

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ABSTRACT

Holstein and Ayrshire heifer calves were barn-fed at high or moderate planes of nutrition from birth until 2, 4 or 6 months of age and then turned to pasture for 2 months. During the first 2 months of the initial barn feeding period body weight and heart girth increases were significantly greater on the high plane of nutrition but differences in withers heights were not significant. However, in the second 2 months increases for all three growth criteria were significant on the high plane of nutrition. During the 2-month pasture period calves in each group grew satisfactorily except Ayrshires on the moderate plane of nutrition. Two-month-old calves on the high plane of nutrition retained their weight advantage over the comparable age group on moderate nutrition. A highly significant trend indicated weight increase to be inversely proportional to age for the first month of the pasture season but the reverse was true for the next month on pasture. Growth patterns to the end of a second pasture season showed that treatment differences had largely disappeared and all animals had attained weight, heart girth, and withers height to within ±4 per cent of Ragsdale standards.

INTRODUCTION

Recommendations for the rearing of replacement dairy stock in this country have not kept pace with developments in the use of pasture for young dairy calves. Several reports have indicated high digestibility of forage by young dairy calves (1, 6, 8). New Zealand workers (7) recommend rotational grazing to provide high quality pasture as a major dietary constituent from 3 weeks of age and as the sole subsistence from 8 weeks of age.

The feeding of dairy heifers at high levels of nutrition in the barn is of questionable economic and practical merit. Replacement stock fed at moderate or relatively low nutritional levels before first calving have superior milking characteristics in later lactation and have a longer herd life than heifers reared on more liberal diets (2, 3, 10).

While various intensities of feeding prior to pasturing have been employed (4, 11), it was considered important to determine the combined effects of initial plane of nutrition and age when pastured on the ability of calves to utilize pasture forage as the sole source of nutrients.

EXPERIMENTAL PROCEDURE

Fourteen Holstein and six Ayrshire female calves from the Central Experimental Farm herds were classed in birth groups by month of birth. Calves of the three groups — December-January; February-March; and

[1]Joint contribution from Animal Research Institute, Research Branch, Ottawa, Ont. (Contribution No. 49), and from Statistical Laboratory, Purdue University, Lafayette, Indiana.

TABLE 1.—DESIGNATION OF HEIFER CALVES TO TREATMENTS SHOWING BIRTH WEIGHT (POUNDS)

Birth group		Pre-pasture ration	
		m - Moderate	*h* - High
Dec.-Jan.	Born during December and January. To pasture 168 days of age.	80 (H) 92 (H) 90 (H) 101 (H)	91 (H) 83 (H) 84 (H) 78 (H)
Feb.-March	Born during February and March. To pasture at 112 days of age.	80 (H) 73 (A) 92 (H)	97 (H) 103 (H) 85 (H)
April-May	Born during April and May. To pasture at 56 days of age.	61 (A) 70 (A) 73 (A)	71 (A) 95 (H) 71 (A)

(H) = Holstein
(A) = Ayrshire

April-May — were started on pasture randomly during late May through late July as they reached ages of 168, 112 and 56 days respectively. The calves in each birth group were assigned randomly at birth to two ration schedules, *m*, moderate plane, and *h*, high plane of nutrition, as shown in Table 1.

All calves received their dam's milk and were limited to 8 pounds daily during the first week. Alfalfa hay (8.6 per cent crude protein, dry matter basis) was fed twice daily beginning the second week of age. The level of all dry feeds was adjusted so that orts approximated 10 per cent of that offered.

Body measurements were taken at 2-week intervals from birth to the end of the first pasture season.

Moderate Ration Schedule (m)

The calves were changed during the second week from whole milk to 10 pounds reconstituted skim milk daily until they were weaned during the seventh week. "C.E.F. Simplified Starter" detailed in an earlier paper (5), with slight modification as to vitamin source (Vitamin A and D added at 1 and 0.4 million I.U. respectively per 100-pound starter) was fed beginning the second week in two feeds up to a limit of 4 pounds daily. The starter was replaced by "Ottawa Grower" (5) after 112 days and fed (group December-January) at the same rate until the calves were put on pasture.

High Ration Schedule (h)

Calves were fed whole milk at 10 per cent of body weight daily until the ninth week when they were changed to reconstituted skim milk. Group April-May calves were abruptly changed to pasture at 56 days. For groups December-January and February-March skim milk feeding was continued at the same rate until the calves were weaned during the 16th week.

The same type of starter as for moderate feeding was fed, beginning the second week, in two feeds to a limit of 6 pounds daily and changed to grower after 112 days. Meal, hay and milk were not fed to calves on pasture.

Pasture

Irrigated legume-grass permanent pasture was rotationally grazed by calves for the 56-day pasture period. Representative herbage samples taken periodically from the pasture averaged 20 per cent crude protein (dry matter basis). All calves had access to salt, bone meal and artificial shade. Feces samples were collected and examined monthly for presence of strongyle ova. All calves were sprayed with methoxychlor at 3-week intervals to control flies.

Second Season

Following the first pasture season all calves were grazed together without supplement till October 1, then wintered under uniform conditions with roughage fed *ad lib.* and meal (grower) limited to 4 pounds/animal/day until animals were 1 year of age. They were free-range grazed as yearling heifers on non-irrigated permanent pasture for 165 days during the second season. Body weights were taken at the beginning and end of this period.

Analysis of Data

The method of least squares was used to analyse the data. For the barn feeding period age groups were ignored. All of the resulting two-way classifications (0-56 days) were analysed using the weighted squares of means procedure. The data for the period 57-112 days, which included only one Ayrshire in the moderately fed February-March sub-group, were deleted, leaving 13 Holsteins. Data for Holsteins for this and the subsequent barn feeding period were analysed by simple analysis of variance techniques.

All pasture data were analysed using multiple regression techniques. Except for final weight the equation fitted for each variable was of the form:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_3^2 + b_5X_1X_2 + b_6X_1X_3 + b_7X_2X_3$$

X_1 = score for breed = 0 for Holstein
1 for Ayrshire

X_2 = score for ration = 1 for ration *m*
2 for ration *h*

X_3 = score for birth group = 1 for Group Dec.-Jan.
3 for Group Apr.-May
2 for Group Feb.-Mar.

For final weight, the equation fitted was of the form:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_3^2 + b_6X_1X_2 + b_7X_1X_3 + b_8X_2X_3$$

where X_1, X_2 and X_3 are defined as above, and X_4 = age at the termination of the experiment.

RESULTS AND DISCUSSION

Barn Feeding

Feed and estimated TDN consumption data for three 56-day barn feeding periods are presented in Table 2. Data for these periods are for 20, 14 and 8 calves respectively, the 6 calves of birth Group April-May having been put on pasture at 56 days and the 6 calves of Group February-March put on pasture at 112 days of age.

TABLE 2.—FEED INTAKE AS AFFECTED BY RATION DURING BARN FEEDING
(56-day period means)

Ration component	Breed	Experimental period days					
		0–56		57–112		113–168	
		Ration					
		m	*h*	*m*	*h*	*m*	*h*
Whole milk (lb.)	H	71	555		71		
	A	60	461				
Skim milk (lb.)	H	342			1038		
	A	340					
Meal (lb. as feed)	H	60	42	200	182	214	326
	A	53	48	214			
Hay (lb. as feed)	H	38	24	231	144	418	432
	A	24	30	208			
TDN	H	98	131	246	288	340	418
	A	84	122	245			

TABLE 3.—RATION AND AGE EFFECTS ON MEAN-WEIGHT, WITHERS, AND HEART BIRTH INCREASE OF CALVES WHILE BARN FED

Growth criteria	Pre-pasture ration	Birth group					
		Dec.-Jan.			Feb.-March		April-May
		Age (days)					
		0–56	57–112	113–168	0–56	57–112	0–56
Weight increase (lb.)	*m*	53	90	108	55	88	(A)43
	h	67	130	118	(A)46 72	(A)87 134	(A)65
Withers height increase (in.)	*m*	2.8	3.4	3.2	3.0	3.5	61 (A) 3.0
	h	3.8	4.9	3.2	(A) 3.9 3.9	(A) 3.9 4.1	(A) 3.7
Girth increase (in.)	*m*	3.9	5.3	5.2	4.7	6.9	2.6 (A) 4.8
	h	5.6	7.2	5.5	(A) 5.3 6.1	(A) 6.3 7.0	(A) 6.4 5.3

(A) Designates Ayrshire. All others are Holstein.

TABLE 4.—ANALYSIS OF VARIANCE FOR BARN FEEDING PERIOD

Source of variation	Degree of freedom	Mean squares		
		Weight increase	Withers increase	Girth increase
		0–56 days of age		
Rations	1	1224.19**	1.48	8.81**
Breeds	1	163.51	0.12	1.80
Rations X breeds	1	37.98	0.11	0.02
Within groups	16	55.58	0.37	0.68
		57–112 days of age		
Rations	1	5927.48**	3.94**	5.28*
Within rations	11	71.35	0.27	0.60
		113–168 days of age		
Rations	1	200.00	0.001	0.245
Within rations	6	43.67	0.801	1.559

*Significant at $P \leq 0.05$
**Significant at $P \leq 0.01$

The stimulating effect of reduced milk allowance (Ration *m* vs. Ration *h*) on voluntary meal and hay consumption is apparent. Increased consumption of meal and hay to compensate for the lower milk allowance did not, however, increase the mean TDN intake of moderate rationed calves to equal that of calves fed more liberal milk allowances. A summary of the individual increases in body weight, withers height and girth is given in Table 3. Mean squares for these criteria are shown in Table 4.

For the period from birth to 56 days, the mean squares significant at the 1 per cent level are ration mean squares for weight increase and for girth increase (Table 4). In the following barn feeding period, 57-112 days, the ration mean squares for weight increase and withers increase were significant at the 1 per cent level, and the ration mean square for girth increase was significant at the 5 per cent level. These data indicate a different pattern of physiological development for *m* versus *h* calves. High rationed calves carried a higher degree of fleshing and had visibly less paunch development than moderate rationed calves. Unit increases of 1 pound in body weight from 113-168 days were made on 3.1 and 3.5 pounds TDN by the moderate and high rationed calves respectively. The high rationed calves were heavier at the beginning of this period, thus requiring a higher proportion of their nutrient intake for maintenance purposes.

Increases in the three measurements for two 28-day pasturing periods are presented in Table 5.

Pasture (First Season)

Partial regression analysis of data for weight increase for the first 28-day period on pasture showed that, as the age to pasture increased, the weight gain on the average decreased, the partial regression coefficient of 65.54 being significant at the 1 per cent level. Analysis of the data for the following 28-day pasture period indicated that, as age to pasture increased, the weight increment on the average increased. The corresponding partial

TABLE 5.—PRE-PASTURE TREATMENT AND AGE TO PASTURE EFFECTS ON PERFORMANCE OF CALVES WHILE ON PASTURE (28-day periods)

Growth criteria	Pre-pasture ration	Birth group					
		Dec.-Jan.		Feb.-March		April-May	
		Pasture period (days)					
		0–28	29–56	0–28	29–56	0–28	29–56
Weight increase (lb.)	*m*	14	67	39 (A)18	22 (A)31	(A)18	(A)30
	h	2	68	25	42	(A)26 23	(A)42 48
Withers height increase (in.)	*m*	1.2	1.2	0.2 (A) 0.6	2.1 (A) 1.2	(A) 0.7	(A) 1.3
	h	1.2	0.6	0.7	1.2	(A) 1.4 0.5	(A) 1.5 2.2
Girth increase (in.)	*m*	1.7	2.4	1.8 (A) 1.2	1.1 (A) 2.1	(A) 2.3	(A) 2.1
	h	1.3	2.0	1.4	2.0	(A) 2.6 3.3	(A) 2.3 1.5

(A) Designates Ayrshire. All others are Holstein.

regression coefficient of −112.10 was significant at the 5 per cent level. The apparent reversal of the sign for these two regression coefficients results from the method of assigning score for birth group (X_3) as described previously (page 57). Data in Table 5 suggest that these linear trends are due primarily to the difference between the mean weight of Group December-January and that of Groups February-March and April-May combined. The fact that the partial regression coefficient in the first instance is positive and in the second negative might be explained by the fact that Group December-January, being heavier on going to pasture, did actually lose more body weight than Groups February-March and April-May during the first few days on pasture. An alternative explanation, considering the extent of the weight increase of Group December-January calves during both pasture periods, is that these larger animals, which consumed up to twice as much hay during the last 56 days before going to pasture, experienced a greater change in rumen fill than calves in Groups February-March and April-May.

Feces examinations indicated internal parasites were not a major problem. However, during the pasture season, Ayrshire calves of Group April-May, previously moderately rationed, lacked bloom, were listless, and generally less able to cope with the sudden change of feeding practice as compared to their high rationed contemporaries. This could be a factor in inferior pasture performance. If later trials confirm that moderately rationed calves do not readily adjust to the pasture environment at 2 months of age, a higher nutrition level during barn feeding may be warranted.

TABLE 6.—MEAN WEIGHT INCREASE DURING, AND MEAN HEART GIRTH AND FINAL WEIGHT IN RESPECT TO AGE AT CLOSE OF 165-DAY YEARLING PASTURE SEASON

Criteria	Pre-pasture ration	Birth group		
		Dec.-Jan.	Feb.-March	April-May
Final age (days)	*m*	649	(A)565 570	(A)527
	h	640	582	(A)540 547
Weight increase (lb.)	*m*	226	(A)173 216	(A)179
	h	196	193	(A)130 179
Final weight (lb.)	*m*	967	(A)705 854	(A)704
	h	958	880	(A)683 845
Final girth (in.)	*m*	68.6	(A) 62.5 66.0	(A) 61.9
	h	66.8	65.5	(A) 61.5 68.0

(A) Designates Ayrshire. All others are Holstein.

Pasture (Second Season)

Table 6 shows the weight increase of the heifers for the 165-day yearling pasture period. Also included are the weight, girth and ages at the end of that period. The mean weight increase animal/day of moderates (Ration *m*) was 0.15 pounds in excess of that of animals that had been high rationed (Ration *h*) as calves.

General Conclusions

Young dairy replacement calves in this experiment, fed liberal milk or meal allowances or retained on barn feeds longer, attained greater weight for age during that period than their contemporaries. Such liberal feeding is in line with the present philosophy and widely recommended practice of feeding to a weight for age standard. The economic advisability of such practices should be questioned especially in the light of the growth patterns during subsequent periods of abundant cheap feed. Ration *m* animals, apparently exhibiting an inherent trait to attain the same mature size, overcame by the end of the second pasture period the ration effects manifest in the earlier feeding period. It is suggested that the over-all management programs, including attempts to follow optimum economic feeding practice, are considerations antagonistic to the concept that animals should attain certain weights at certain ages. The fact that in this experiment yearling Holsteins in each treatment group were within 2 to 4 per cent, and Ayrshires within 3 to 8 per cent, of Ragsdale weights (9) should thus be taken to mean only that they attained substantial weights as yearlings.

Animals in this experiment were able to consume and effectively utilize unsupplemented pasture as the sole nutrient source at as early an age as 2 months.

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PASTURE FOR YOUNG DAIRY STOCK

II. EFFECT OF PREVIOUS NUTRITIONAL LEVEL AND AGE ON GROWTH OF HOLSTEIN HEIFER CALVES ON PASTURE[1]

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ABSTRACT

Thirty-five Holstein heifer calves were assigned at birth to three ration schedules: moderate *m;* control *c;* high *h*. These three groups were weaned from whole milk during the 2nd, 7th and 9th weeks respectively with *m* and *h* calves receiving skim milk to 7 and 16 weeks of age respectively. *m* and *c* calves were allowed 4 pounds and *h* calves up to 6 pounds of meal daily with no limit on hay consumption. Moderate and high rationed calves were further sub-divided into three birth groups and were abruptly switched from the above feeding schedules and placed on pasture without supplementation at 56, 112, and 168 days. Treatment comparisons included live weight gain, withers height and heart girth measurements.

High rationed calves made greater growth increases than *m* or *c* calves during the barn feeding period. These differences were greater for weight than for heart girth or withers increases. Pastured calves made smaller body gains during the first 28-day pasture period than barn-fed controls. This trend was reversed by the third pasture period with some pastured calves gaining over 2 pounds daily. *h* calves placed on pasture at 2 months of age made greater body weight gains and appeared to be thriftier than calves previously moderately rationed.

INTRODUCTION

In an earlier paper (5) it was shown that dairy calves could consume and efficiently utilize unsupplemented pasture as the sole nutrient source as early as 2 months of age. Moreover, although moderately fed animals weighed less than their high rationed contemporaries on going to pasture at 2, 4 and 6 months of age, they achieved the same weight at 18 months of age on a high roughage feeding program. Supporting evidence that young calves can utilize pasture herbage efficiently for growth has been published by workers in New Zealand (4) and southern United States (3) who recommend excellent pasture along with milk and starting the animals on pasture at 1 to 2 weeks of age. However, feeding liquid diets on pasture is considered a costly and laborious procedure and has not met with general acceptance in Canada. Pasture without liquid diet supplementation might be the simplest and most economical procedure.

Little attention has been given to barn feeding of specific rations to condition calves for maximum utilization of pasture, nor has earliest age at which dairy calves can make satisfactory use of pasture been firmly established. Furthermore, the advisability of feeding dairy calves for maximum weight gain during the pre-pasture barn feeding period was questioned earlier (5). To obtain additional information on these points further studies of barn rations, age to pasture, and growth on pasture were carried out using uniform Holstein heifer calves.

EXPERIMENTAL PROCEDURE

Starting in December 1956, 35 purebred heifer calves were assigned to ration and birth groups, fed and measured as described previously (5). The following were the only modifications of the Experiment I procedure: Only Holstein calves were used, with 13 from the Animal Research Institute herd

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TABLE 1.—DESIGNATION OF HEIFER CALVES TO TREATMENT

Birth group	December-January			February-March			April-May		
Ration schedule[1]	*m*	*h*	*c*	*m*	*h*	*c*	*m*	*h*	*c*
Number of calves	4	4	4	4	4	3	4	4	4
Mean birth weight (lb.)	96	90	83	91	92	92	96	92	96
Age to pasture (days)	168	168	—	112	112	—	56	56	—

[1] *m*—moderate rationed; *h*—high rationed; *c*—barn controls

and 23 of similar breeding produced from local herds. Ration schedule *c* (Table 1) calves were added as barn controls. Controls were fed meal and alfalfa hay (15.5 per cent crude protein, dry matter basis) according to the same schedule as *m* calves, but received 350 pounds of whole milk during the first 7 weeks and were not turned to pasture. Non-irrigated grass-legume pastures (approximately 22 per cent protein) were rotationally grazed for three 28-day periods. The experiment ended at the close of the first grazing season.

Allocation of calves to rations and birth groups is shown in Table 1.

Differences in growth criteria were determined by analysis of variance, using the method of Snedecor (8) for the missing values in the February-March control sub-group.

RESULTS AND DISCUSSION

Barn Feeding — All Treatments

Mean consumption of milk, skim milk, meal and hay are shown in Table 2. Up to 112 days, the reduced amounts of milk fed moderate-rationed and control as compared to high-rationed calves are reflected in greater voluntary consumption of meal and hay.

Other workers (11) have observed increased appetites, particularly for meal, of calves fed reduced milk allowances. From 113 to 168 days of age high-rationed calves ate up to 6 pounds of meal per head daily. During this period moderate-rationed calves, limited to 4 pounds of meal per head daily, ate considerably more hay than high-rationed or control calves.

Mean 56-day increases of the three growth criteria for the barn feeding period are presented in Table 3 and the analysis of variance in Table 4.

Weight, withers height, and girth increases of high-rationed calves were greater than those of moderate-rationed and control calves in each of the three 56-day periods with one exception (moderate-rationed, 113-168 days). Ration effects measured by weight differences were highly significant ($P = 0.01$) in the 57-112 day period. Ration effects on girth and withers height were less pronounced ($P = 0.05$) in the same period. Percival (6) found similar growth relationships in early weaned calves that gained 80 per cent as much weight but made 90 per cent as much skeletal measurement increase as calves fed more milk.

TABLE 2.—MEAN 56-DAY CONSUMPTION OF WHOLE MILK, SKIM MILK, MEAL, HAY AND T.D.N. BY HEIFER CALVES OF THREE BIRTH GROUPS, FED THREE RATION SCHEDULES

Age (days)	0–56			57–112			113–168		
	Ration schedule								
Birth group	*m*	*h*	*c*	*m*	*h*	*c*	*m*	*h*	*c*
				Whole milk (lb.)					
December-January	79.6	562.4	346.8		66.8				
February-March	76.1	372.3	352.2		64.5				
April-May	81.2	470.8	351.5						
				Reconstituted skim milk (lb.)					
December-January	330.7				966.6				
February-March	341.0				970.5				
April-May	335.1								
				Meal (air dry, lb.)					
December-January	46.6	19.6	46.3	206.0	130.8	215.4	224.0	328.0	224.0
February-March	78.3	27.6	42.3	223.0	180.6	216.1			
April-May	78.7	31.3	46.3						
				Hay (air dry, lb.)					
December-January	36.4	17.3	34.1	173.7	96.6	158.8	396.4	323.6	326.2
February-March	15.7	7.5	33.5	136.6	93.5	175.0			
April-May	24.8	13.7	23.5						
				T.D.N. from all ration ingredients					
December-January	89	110	101	223	224	222	336	368	302
February-March	104	115	102	216	256	230			
April-May	109	104	100						

TABLE 3.—MEAN 56-DAY INCREASE OF THREE BODY MEASUREMENTS OF HEIFER CALVES, DURING BARN FEEDING PERIOD

Age (days)	0-56				57-112				113-168			
	Ration schedule											
Birth group	*m*	*h*	*c*	Mean	*m*	*h*	*c*	Mean	*m*	*h*	*c*	Mean
						Weight (lb.)						
December-January	46	57	53	52	95	122	91	103	104	112	105	110
February-March	56	52	51	53	92	136	94	107				
April-May	55	62	50	56								
Mean	52	57	52	54	93	129	93	105	104	122	105	110
						Withers height (in.)						
December-January	2.8	3.5	3.2	3.2	3.3	4.1	3.6	3.7	3.8	3.6	3.4	3.6
February-March	3.1	3.5	3.4	3.3	3.8	4.8	3.5	4.0				
April-May	3.3	4.0	3.0	3.4								
Mean	3.0	3.7	3.2	3.3	3.5	4.5	3.6	3.8	3.8	3.6	3.4	3.6
						Heart girth (in.)						
December-January	4.1	5.0	5.6	4.9	6.2	7.2	5.8	6.4	4.8	5.5	4.4	4.9
February-March	4.7	4.7	4.8	4.8	6.0	7.6	5.9	6.5				
April-May	4.2	5.5	4.0	4.6								
Mean	4.4	5.1	4.8	4.8	6.1	7.4	5.9	6.5	4.8	5.5	4.4	4.9

TABLE 4.—ANALYSIS OF VARIANCE OF GROWTH DATA, DURING BARN FEEDING PERIOD, OF HEIFER CALVES

Age (days)	0-56		57-112		113-168	
Source of variance	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
			Weight			
Total	34		22		11	
Birth groups	2	47.58	1	117.04		
Rations	2	112.33	2	3717.04**	2	420.23
Birth groups x rations	4	93.79	2	146.54		
Error	26	107.07	17	114.16	9	142.44
			Withers height			
Total	34		22		11	
Birth groups	2	0.26	1	0.77		
Rations	2	1.33	2	2.19*	2	0.12
Birth groups x rations	4	0.27	2	0.46		
Error	26	0.47	17	0.39	9	0.31
			Heart girth			
Total	34		22		11	
Birth groups	2	0.30	1	0.02		
Rations	2	1.63	2	5.42*	2	1.25
Birth groups x rations	4	1.60	2	0.22		
Error	26	0.72	17	1.06	9	0.48

*$p \leq 0.05$
**$p \leq 0.01$

TABLE 5.—MEAN 28-DAY INCREASE OF THREE BODY MEASUREMENTS OF HEIFER CALVES ON PASTURE, GROUPED BY PRE-PASTURE RATION SCHEDULE AND BIRTH GROUP, IN RELATION TO BARN FED CONTROLS

Pasture period (days)	0–28				29–56				57–84			
Ration schedule	*m*	*h*	*c*		*m*	*h*	*c*		*m*	*h*	*c*	
Birth group	Pasture		Barn	Mean	Pasture		Barn	Mean	Pasture		Barn	Mean
					Weight (lb.)							
December-January	14	00	35	16	65	57	46	56	64	65	26	52
Febuary-March	21	23	52	32	52	56	70	60	52	61	35	50
April-May	18	23	39	26	44	46	51	48	46	52	58	52
Mean	17	15	42	25	54	53	54	53	54	60	40	51
					Withers height (in.)							
December-January	0.6	0.3	1.1	0.7	0.9	1.1	1.1	1.0	0.9	0.7	1.1	1.3
February-March	1.0	0.7	1.1	0.8	1.1	1.8	2.1	1.6	1.4	0.7	0.8	1.0
April-May	0.6	0.5	1.2	0.8	1.3	1.2	1.4	1.3	1.0	1.6	1.3	1.3
Mean	0.8	0.5	1.2	0.8	1.1	1.3	1.5	1.3	1.1	1.0	1.1	1.1
					Heart girth (in.)							
December-January	2.1	1.0	2.7	1.8	3.0	2.6	2.2	2.6	2.5	2.7	1.9	2.4
February-March	1.9	2.4	2.7	2.3	3.4	3.4	3.3	3.4	2.6	2.6	1.9	2.4
April-May	2.6	2.1	2.3	2.3	2.4	2.8	2.9	2.7	2.9	2.7	3.1	2.9
Mean	2.2	1.8	2.5	2.2	2.9	2.9	2.8	2.9	2.7	2.7	2.3	2.6

High-rationed calves developed higher fleshing and less paunchiness than moderate-rationed and control calves. Increased reticule-rumen size of high roughage-consuming calves have been demonstrated by other workers (2, 10).

Pasture Periods (Treatments m and h and Comparison with Barn Fed Controls)

The effect of age and previous levels of feeding on body measurement increases during the pasture period is shown in Table 5 and analysis of variance in Table 6.

The adjustment period for moderate and high-rationed calves, abruptly changed to pasture, did not appear to have lasted longer than the first 28-day period. Birth group effect on gain was significant (P = 0.01), with 168-day old calves (Group December-January) showing the smallest weight increases. For the first period, ration effect as measured by all three growth criteria was significant (weight P = 0.01, withers and girth P = 0.05), with previously high-rationed calves making the smallest increases. Janet Tibitts (9) found the same trend in weight gain of calves fed high versus low milk allowances when changed to high roughage rations. Slowed growth rates, exhibited by calves during the initial pasturing period, do not necessarily result in permanent harmful effects (1, 4), and should not be viewed with alarm, especially if animals so treated are able to make satisfactory performance subsequently. With no significant ration effects in the second pasture period (29-56 days) such satisfactory performance would appear to have been attained. Indeed, by the third pasture period the significant (P = 0.01) ration effect on weight indicates greater gains by pastured calves than by barn-fed contemporaries.

TABLE 6.—ANALYSIS OF VARIANCE OF GROWTH DATA OF HEIFER CALVES ON PASTURE RELATED TO BARN FED CONTROLS

Pasture period (days)		0–28	29–56	57–84
Source of variance	D.F.	M.S.	M.S.	M.S.
		Weight		
Total	34			
Birth groups	2	768.36**	493.70	26.86
Rations	2	2683.53**	20.19	1284.93**
Birth groups x rations	4	185.09	351.48	772.11**
Error	26	138.86	170.43	163.64
		Withers height		
Total	34			
Birth groups	2	0.20	1.18	0.54
Rations	2	1.42*	0.57	0.04
Birth groups x rations	4	0.08	0.60	0.54
Error	26	0.34	0.48	0.37
		Heart girth		
Total	34			
Birth groups	2	0.67	2.16	1.10
Rations	2	1.61*	0.06	0.60
Birth groups x rations	4	1.16	0.71	0.88
Error	26	0.43	0.75	0.64

*P ≤ 0.05
**P ≤ 0.01

The ration x birth-group interaction (weight) (Table 6) approached significance in pasture period 2 ($P = 0.05$) and was highly significant in period 3. This reflects a reduction in rate of growth of controls with increasing age, and a differential response to pasture by calves of different ages (Birth Groups) and previous nutritional treatment (Rations *m* and *h*).

In the second and third 28-day pasture periods height at withers was similar for all ration and birth groups. This suggests that for dairy replacement heifers conclusions drawn from body weight gains alone could give preference to the least economic rations. Contrary to generally accepted practice, therefore, we recommend that height at withers should replace body weight as the primary criterion for response of dairy replacement heifers to feeding and management.

Strongyle ova counts and visible thrift of calves indicated that none of the animals was seriously infected. Preston (7) states that in Great Britain worm infestation can be serious when calves with low intake graze dry summer pasture.

We conclude that high quality pasture can be used as the satisfactory sole diet of 2- to 6-months-old Holstein heifer calves, provided good husbandry and pasture management are practised, and a moderate growth rate is believed to be more conducive than maximum body weight gains to ultimate milk-producing ability. Liberal milk and meal feeding of calves intended for pasture at 4 to 6 months of age is of questionable merit.

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PRELIMINARY OBSERVATIONS IN THE USE OF A SUSTAINED RELEASE PELLET FOR ADMINISTRATION OF CHROMIC OXIDE TO SHEEP IN DIGESTIBILITY STUDIES

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ABSTRACT

Sustained release pellets of chromic oxide (Cr_2O_3) were administered to sheep every second day for 112 days, to serve as an external indicator in digestibility determinations of mixed rations. The pellets were made from a mixture of Cr_2O_3 and dental plaster in the ratio of 2:1. A pressure of 10,000 p.s.i. produced a pellet with a specific gravity of 2.8.

Digestibility coefficients obtained by the Cr_2O_3 ratio method differed markedly from those obtained in a conventional digestibility trial and the apparent recovery of Cr_2O_3 from feces samples showed a coefficient of variation of 27 per cent. Recovery of pellets from the alimentary tracts of the slaughtered sheep showed that the disintegration time of the pellets was correlated with the proportions of alfalfa ($r = -0.83$), wheat straw ($r = 0.36$), and oat grain ($r = 0.80$) in the rations. Indications were that some pellets were lost by passing into the abomasum where immediate disintegration occurred, or by regurgitation, although the latter had not been noticed in this experiment.

INTRODUCTION

Chromic oxide (Cr_2O_3) fed to sheep (1) and cattle (6, 8, 10) has been used as an indicator substance for digestibility determinations. The variability of its concentration in the feces throughout the day has been found to depend in part upon the method and frequency of administration (3, 5, 7, 9, 11, 13, 14, 16). When administered in gelatine capsules, six doses were required daily to give a uniform concentration (3). Since this was considered impractical, a sustained release pellet (SRP) was developed for cattle (3, 11) and suggested for sheep[1].

In this experiment SRP's containing Cr_2O_3 were administered for the purpose of studying their usefulness in digestibility experiments with sheep.

EXPERIMENTAL PROCEDURE

SRP's were made from Cr_2O_3 and dental plaster ($CaSO_4 \cdot \frac{1}{2} H_2O$)* in the ratio of 2:1 (w. w) by placing 7.6 grams of this mixture plus 2 millilitres of water in a ¾-inch die and subjecting it to a pressure of 10,000 p.s.i. for about 5 seconds. This procedure produced a pellet with a specific gravity of 2.8. After air drying, each pellet was trimmed to contain exactly five grams of Cr_2O_3 and coated with Carbowax 4000 (11) to minimize Cr_2O_3 loss during storage and to facilitate administration to the animals.

The experiment was planned as a three by three factorial design replicated over four periods and containing four wethers per treatment. The treatments were three levels of digestible energy (DE) and three levels of crude protein (CP). The four consecutive periods lasted for 28 days each. Thirty-six yearling Rambouillet wethers were allotted at random to the nine rations on which they were kept during the four periods.

The rations were composed of second-cut Rambler alfalfa, wheat straw, and oat grain. The DE in these ingredients was estimated by Schneider's

[1]Pigden, W. J. *Private communication.*
*Western Dental Plaster, Western Gypsum Products Ltd., Winnipeg, Man.

TABLE 1.—CHEMICAL COMPOSITION OF THE INDIVIDUAL RATION INGREDIENTS
(per cent of dry matter)

	Crude protein	Crude fibre	Ether extract	N-free extract	Ash	Digestible energy
Alfalfa	21	27	2	40	10	65
Wheat straw	3	40	1	49	7	47
Oats	16	11	5	65	3	76

TABLE 2.—FORMULATION OF RATIONS

Digestible energy (%)	Ration ingredients (%)	Crude protein content of ration (%)		
		12	14	16
60	Alfalfa	31	52	72
	Straw	43	35	28
	Oats	25	13	0
62.5	Alfalfa	21	41	61
	Straw	39	31	23
	Oats	40	28	16
65	Alfalfa	9	29	50
	Straw	35	27	19
	Oats	56	44	31

equations (18) on the basis of their chemical composition (Table 1). The ingredient composition of the rations (Table 2) was calculated to comply with the levels of DE and CP shown in Table 2. The alfalfa was fed as hay cut in a forage harvester in 1-2 inch lengths. As a measure against selective sorting of the feed mixtures, the wheat straw was shredded through a coarse screen in a hammer mill to a texture somewhat finer than that of the alfalfa. The oats were fed as whole grain.

The ration ingredients were weighed out in the required proportions for each meal. The sheep were fed in individual feeding stalls to which they were confined from 7.30 to 8.30 a.m., and from 3.30 to 4.30 p.m. daily. Each was fed as much as it would eat without refusing any portion of the ration. Between feeding periods the sheep had free access to water and minerals in the corral. During the collection periods the intakes were held as constant as possible. SRP's were administered at 8.30 a.m. every second day throughout the experiment.

During the fourth week of each period grab samples of feces were collected daily for 5 consecutive days. One defecation was collected during each feeding period. These collections were bulked into a sample for each sheep in each period. The samples were macerated in a batch mixer and sub-sampled. The sub-samples were diluted with water and homogenized in a Waring blender to the consistency of a creamy paste which was poured into half-ounce paper portion cups and frozen for storage until the time

of analyses in the laboratory. Chromic oxide analyses were carried out by the wet ashing procedure described by Bolin *et al.* (2), as modified by Crampton and reported by Troelsen (19).

At the termination of the experiment the sheep were slaughtered. The alimentary tracts were separated into the various organs. The content in each organ was weighed, sorted for remnants of SRP's, and sampled for dry matter and Cr_2O_3 determinations.

The nine rations (Table 2) were also fed to sheep in digestion stalls in a factorial design replicated four times. Total feed intake and fecal production from this trial provided conventional digestibility coefficients for comparative purposes.

The performance data and carcass analyses of the wethers will be published in another paper.

RESULTS AND DISCUSSIONS

Digestibility coefficients calculated by the Cr_2O_3 ratio method varied too much to show significant differences between the rations. Indeed, some values were negative and some approached unity. In comparison to the data from the conventional trial in the digestion stalls (Table 3) the Cr_2O_3 ratio did not produce reliable digestibility coefficients. Apparently the SRP's did not distribute the Cr_2O_3 evenly enough in the feces to facilitate the use of grab samples in digestibility determinations by the ratio method.

The rate of disintegration of SRP's in the alimentary tract varied between animals and rations. This was determined by the numbers of pellets recovered from the slaughtered sheep. The averages for rations are listed in Table 4. Since the pellets were administered regularly at 48-hour intervals, the mean disintegration time in days is arrived at by doubling these figures. The rations apparently affected the disintegration time as a difference of 12 was significant at the 5 per cent probability level (17). Although the disintegration rate quite definitely increased with decreasing DE level and increasing CP level, it cannot be overlooked that the ingredient composition of the rations (Table 2) could be the determining factor. Thus,

TABLE 3.—PER CENT DIGESTIBLE DRY MATTER BY THE CONVENTIONAL DIGESTIBILITY TRIAL

Digestible energy (%)	Crude protein content of ration (%)			Mean
	12	14	16	
60	62.9	63.8	62.6	63.1
62.5	63.8	64.9	64.5	64.4
65	66.1	64.9	66.5	65.8
D[1]	2.3			1.3
Mean	64.2	64.5	64.5	64.4
D	1.3			

[1]Difference to be significant at P=0.05 (17)

TABLE 4.—AVERAGE NUMBER OF PELLETS RECOVERED BY RATIONS

Digestible energy (%)	Crude protein content of ration (%)		
	12	14	16
60	14	6	4
62.5	24	10	5
65	37	19	8
D	12		

TABLE 5.—MEAN CONCENTRATION OF Cr_2O_3 IN THE ALIMENTARY TRACTS OF 36 SHEEP (other than pellets recovered)

Organ	Per cent Cr_2O_3	Coefficient of variation[1]
Rumen	.06	34%
Reticulum	.20	37%
Omasum	.24	143%
Abomasum	.54	46%
Small intestine	.18	54%
Large intestine	.45	17%
Caecum	.47	23%

[1]Standard deviation as per cent of mean

disintegration time of the SRP's was correlated with the proportions of alfalfa ($r = -0.83$, $P < 0.01$), oats ($r = 0.80$, $P < 0.01$), and wheat straw ($r = 0.36$, $P < 0.05$).

The rations did not affect the location of recovery of the pellets in the alimentary tracts. Of all recoveries 24 per cent were in the rumen, 75 per cent in the reticulum, a trace in the omasum, and 1 per cent in the abomasum. None was found in the small intestine, large intestine, or caecum, indicating that no excretion of pellets occurred. In most cases it was possible to array the recovered pellets in graduated order of size which indicated that the pellet disintegration was proportional to surface area and to length of time in the animals. However, the intervals in the arrays were not uniform enough to establish whether pellets were missing.

Traces of disintegrating pellets were observed in the abomasum in 17 of the sheep. Distinctly isolated areas of 1.5 to 2 inches in diameter were set off from the surrounding material by a concentrated green colour of Cr_2O_3. This phenomenon could only be explained by a disintegration of relatively large pellets at a rate exceeding that by which the peristaltic motions of the abomasum dispersed the fragments. An example is shown in Figure 1.

The concentration of Cr_2O_3 (other than pellets recovered) in the various organs of the alimentary tract of each sheep, was determined. No significant differences were observed between rations, CP levels, DE levels,

FIGURE 1. Disintegrated SRP's of Cr_2O_3 in abomasum content. The darker areas contain high levels of Cr_2O_3 evident by a concentrated green colour.

or alfalfa levels. The mean values and corresponding coefficients at variation are shown in Table 5. The higher coefficient of variation for omasum, abomasum, and small intestine could indicate an uneven transfer of Cr_2O_3 from the rumen and reticulum into the succeeding organs. The lower coefficients for the large intestine and caecum would partly be due to the disappearance of digestible dry matter from the ingesta along the intestinal tract.

The recovery of Cr_2O_3 in the feces from the individual sheep in each of the four collection periods was calculated by the formula:

$$\% \text{ recovery of } Cr_2O_3 = \frac{A \times B \times C}{100\ D}$$

where:

A = feed intake (grams dry matter per day)
B = 100 − (per cent digestible dry matter)
C = observed Cr_2O_3 in feces (per cent of dry matter)
D = grams of Cr_2O_3 administered to each sheep daily.

The per cent digestible dry matter was obtained from the conventional digestibility trial. Whenever the disintegration time of the SRP's, as determined by the numbers of pellets recovered from the slaughtered sheep, exceeded the interval between the initial administration of pellets and any given feces collection period, the Cr_2O_3 administered (D in above formula) was adjusted by multiplying it by the ratio of this interval and the disintegration time.

The recoveries of Cr_2O_3 by rations are reported in Table 6. The relatively low values throughout could partly be due to a higher digestibility of the rations by the sheep in the conventional digestibility trial as compared to the sheep in the SRP trial, or to regurgitation of pellets as observed by Corbett *et al.* (3), as well as by the author in an experiment now in progress. A higher digestibility by the sheep in the digestion stalls could be expected since their feed intake was lower ($P < 0.01$) than that of the animals in the SRP trial. A similar phenomenon has been observed by Raymond *et al.* (15). There is only one significant difference in the between-treatment data, namely, in the 65 per cent DE rations where 16 per cent CP gave higher recovery than 12 and 14 per cent CP. It is noticeable that a low recovery prevails in the rations that caused a slow disintegration of pellets.

TABLE 6.—RECOVERY OF CHROMIC OXIDE (PER CENT)

Digestible energy (%)	Crude protein content of ration (%)		
	12	14	16
60	83	80	81
62.5	67	84	81
65	69	67	94
D	19		

Coefficient of variation: 27%

This could be due to an inadequate adjustment for the disintegration time of the SRP's in amount of Cr_2O_3 administered (D in the formula above) which would occur if pellets were missing from the array recovered in the alimentary tract of an animal.

As the experiment progressed the percentage recovery of Cr_2O_3 decreased. The mean values for periods 1, 2, 3 and 4 respectively were 91, 82, 71 and 71 per cent. A difference of 11 percentage units was significant at $P = 0.05$. The reason for this tendency was not revealed by the data obtained. The discrepancy in the recovery of Cr_2O_3 between treatments, periods and replicates was indicated by a coefficient of variation of 27 per cent. Although the Cr_2O_3 administered was adjusted for the disintegration rate of the SRP's in each animal, the distribution of Cr_2O_3 in the feces was not uniform enough to yield reliable digestibility coefficients by the indicator ratio method from feces grab samples. Further studies are needed to reveal the reasons for this.

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WOOL AND BODY GROWTH IN LAMBS DURING THE FIRST 14 MONTHS OF LIFE[1]

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ABSTRACT

Data from 290 grade Corriedale sheep, ranging from 1 to 428 days of age, were used to study the relationships between age and the following characteristics: body weight, staple length, fibre thickness, and clean fleece weight. The difference between means and regressions for sex and type of birth also were evaluated.

Body weights increased during the growth period from 50 to 428 days of age but, after 300 days, approached constancy asymptotically. The body weights of single lambs were greater ($p < .01$) than those of twins; also, wethers were heavier than females at all ages. The average daily rate of gain was higher, though not significantly, for singles and wethers than for twins and females, respectively. However, in the single lambs, the difference in rate of gain between wethers and ewes was significant ($p < .05$).

Staple lengths showed a declining growth rate with progressing age whereas fibre cross-sectional area showed a linear increase.

The increase in clean fleece weight with age was expressed by a quadratic function. The difference in fleece weights between sexes were negligible and the rates of increase were essentially the same. However, there were significant differences ($p < .01$) in means and regressions between singles and twins.

INTRODUCTION

In a previous paper, Slen and Banky (15) presented the relationships between annual fleece weight and age in sheep during the period from 1 to 7 years. It was found that significant changes in clean fleece weights occurred during the sheep's lifetime and were reflected in total production. However, it is during the first year of life that body size, together with the various wool characteristics such as fibre length, fibre thickness, and fibre population per unit of skin area undergo pronounced changes. Consequently, it is during this critical period of life that information on the relationship between wool production and age is of considerable importance to the animal breeder. Burns[3] measured the average fibre thickness and staple length of wool samples taken at monthly intervals from measured skin areas on lambs. He noted that the growth rate of staple length remained uniform whereas fibre thickness tended to increase to 1 year of age. Botkin *et al.* (3) determined the staple lengths of wool from Rambouillet lambs at 128 and 202 days of age and found that staple length depended primarily on age and that the relationship was affected very little by either sex or type of birth.

Belič (1) determined the fibre thickness of Tsigai lamb wool at monthly intervals from birth to 15 months of age. Average fibre thickness increased from 20 microns at birth to 30 microns at 8 months of age but no further change occurred thereafter. In Tsigai x Merino lambs Belič and Petrovic (2) found that fibre thickness reached its maximum at 2 months of age and the same trend held for purebred Merinos. It should be pointed out that in measuring fibre thickness they took samples of small locks at

[1]Contribution from the Animal Science Section.
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monthly intervals from parts of the skin adjacent to previously sampled areas and measured each fibre at its mid-point. This measurement at the mid-point tends to halve the monthly increments so that in the above studies changes actually were measured up to about 7.5 rather than 15 months of age. Thus, it appears that fibre thickness became stable at 3 to 4 months of age in the Tsigai and at 1 month of age in Merinos and crossbreds.

Changes due to age in the wool quality of 75 Navajo ewe lambs were evaluated by Crandstaff and Blum (8). The proportion of hair and kemp fibres in the fleece gradually decreased from the 28th day and reached constancy at about 3 months of age.

Fibre number per unit of skin area is known to increase with age. These changes may be conveniently expressed by the ratio of secondary to primary follicles (S P). In so doing, it is assumed that the number of fibres grown from the primary follicles is constant throughout life so that an increase in the S/P ratio is a direct expression of changes in the secondary follicle (and, thus, fibre) population. Marston (12), using estimates made by Carter, showed that the S P ratio in Merino lambs increased rapidly up to about 100 days of age with constancy being reached asymptotically at about 20 months of age. This increase was found to be dependent on the nutritional environment, since the maturation of the secondary follicle was greatly retarded under adverse conditions.

According to Brody (4), body growth pattern is a function of time and in sheep may best be characterized by a sigmoid curve. In general, weight increases rapidly from birth until the point of inflection is reached at about 2 months of age and from then on growth rate decreases gradually.

Donald and McLean (7), Phillips and Dawson (13), Karam *et al.* (11), Hazel and Terrill (10), and Guyer and Dyer (9) have demonstrated that male lambs have generally higher birth weights and gain at a faster rate than females. Recently, workers at the University of California (5) found no significant differences between sexes at birth, but marked differences in both weights and growth rates became evident as the lambs grew older.

The type of birth appeared to have a marked effect on both birth weights and rates of gain in young lambs. DeBaca *et al.* (6) studied the effect of a number of environmental factors on the weight gains of crossbred lambs and found type of birth to be the most important. In this experiment single lambs were not only heavier at all ages up to 13 weeks but also gained at a faster rate. These workers suggested that the advantage of singles over twins was due partly to the higher birth weights of the single lambs. In addition, Donald and McLean (7) and Phillips and Dawson (13) have shown that heavier lambs at birth tend to increase their weight more rapidly. On the other hand, Guyer and Dyer (9) attributed the higher rate of growth in single lambs to the influence of better nutrition during the nursing period. In accordance with this, recent work at the Universities of California and Wyoming (3, 5) suggested that weight differences due to type of birth are most important at birth but tend to diminish with advancing age.

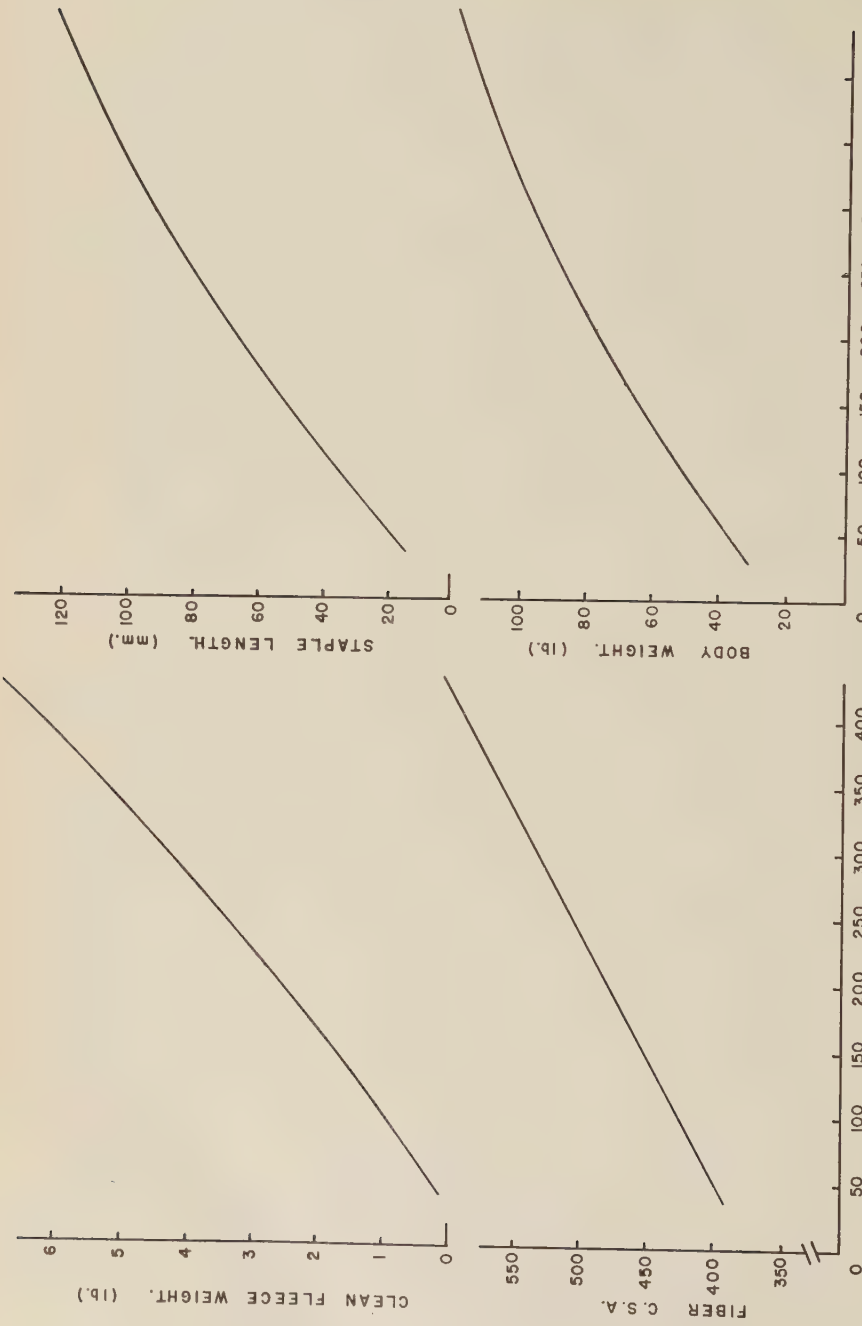

FIGURE 1. The relationship of certain fleece characteristics and body weights (30-day average) to age in young sheep.

The present study was undertaken to obtain data on the quantitative relationships between age and clean fleece weight, single fibre characteristics, and body weight in sheep from birth to 14 months of age. Such data are needed in estimating fleece weights in young lambs, in correcting shearling fleece weights to 1 year of age, and in determining the relative role of the single fibre characteristics in contributing to fleece weight.

MATERIALS AND METHODS

The data used in this study were obtained from 290 grade Corriedale sheep, ranging from 1 to 428 days of age and born in 1952, 1953, and 1954. No changes were made in the breeding policy of using grade Corriedale ewes and good quality purebred Corriedale rams during this time. Therefore, the flock was considered to represent the same genetic material. In addition, every effort was made to standardize feeding and management of the lambs from year to year. The regressions of the four characters studied on age within the years 1952, 1953, and 1954 were calculated and, because they did not differ significantly, the data were considered to have a similar environmental background and were pooled.

The lambs were born in April and May and maintained under a management system that permitted normal growth and development. Docking and castration were performed at about 2 weeks of age. The lambs remained with the ewes until weaned at approximately 5 months of age.

In each of the years 1952, 1953, and 1954 the lambs used in this experiment were divided into 13 groups, with 10 lambs in each the first year and 8 in each the latter 2 years. Six lambs died during the experimental period. Data obtained from twins raised as singles were eliminated.

The first group of lambs was shorn when the average age was approximately 50 days; successive groups were shorn at approximately 30-day intervals thereafter. A Stewart flexible shaft shearing machine was used on each group. These lambs were weighed immediately after shearing and the weight of grease wool recorded. The fleeces then were placed in plastic bags, brought into the laboratory, where they were sub-sampled if too large (i.e., over 400 grams), and the clean fleece weight, staple length, and fibre thickness determined.

The fleece analyses were made by standard methods employed in this laboratory and described previously (14, 16). It should be pointed out that the fibre thicknesses were measured at approximately the mid-portion of the staple causing errors similar to those discussed previously in the data of Belič (1, 2). The staple length was the average of measurements on 10 randomly selected staples per fleece. Complete records were available on birth dates and on the life histories of the lambs and, therefore, it was possible to calculate the length of time from birth to shearing for each lamb. For purpose of analysis the data were divided into four groups, i.e., single males, single females, twin males, and twin females.

RESULTS AND DISCUSSION

Table 1 shows the periodic averages for body weight, clean fleece weight, staple length, and fibre cross-sectional area (CSA) together with the corresponding average age.

TABLE 1.—PERIODIC AVERAGES OF AGE, BODY WEIGHT, AND THE DIFFERENT WOOL CHARACTERISTICS IN GRADE CORRIEDALE LAMBS FROM BIRTH TO 14 MONTHS OF AGE (1952-54 INCLUSIVE)

Age (days)	No. of lambs	Average				
		Clean fleece weight (lb.)	Staple length (mm.)	Body weight (lb.)	Fibre thickness (u)	Cross-sectional area (sq. u)
50.6	23	.39	20.2	34.2	23.1	419
74.3	23	.61	27.6	42.1	22.8	408
108.6	21	1.19	41.0	57.6	23.4	430
137.9	21	1.52	48.4	62.8	22.8	409
166.6	21	2.09	56.7	74.0	25.3	502
197.5	23	2.58	64.8	80.1	24.0	452
227.7	23	3.01	72.3	81.8	25.6	516
256.1	22	3.50	80.4	83.3	25.8	552
285.0	20	4.24	89.1	94.4	26.8	562
314.9	26	4.62	95.4	98.2	26.1	536
344.9	22	5.27	106.8	101.0	26.5	552
375.0	23	5.42	110.1	103.1	26.5	551
405.5	23	6.72	116.8	119.4	26.8	562
424.8	10	6.64	113.9	118.0	28.7	646

The general relationships of these characteristics to age are presented in Figure 1 for comparative purposes while the specific relationships, based on type of birth, will be discussed in the various sections.

Body Weight-Age Relationships

Body weights of the animals were available for the period from 50 to 428 days of age. According to Brody (4), the steep, or accelerating, phase of growth ends in sheep at about 60 days of age. On this basis it was evident that the data used in this study pertained to the declining, or self-retarding, phase of growth. The data showed a curvilinear relationship between body weight and age and, because of this, the data in each of the four groups, based on sex and type of birth, were fitted to a parabolic function having the following general form:

$$\hat{Y} = a + b_1X + b_2X^2$$

where Y = body weight in pounds and X = age in days.

The resulting regression lines are shown in Figure 2 and the equations are shown in Table 2, in addition to those for Figures 3, 4, and 5.

There were significant differences ($p < .05$) between the average body weights of wethers and ewes after 150 days of age when analysis of covariance was used to control type of birth. Wethers gained at a significantly higher rate ($p < .05$) than ewes and, consequently, were heavier at that age. When the body weights were analysed on the basis of type of birth, significant differences ($p < .05$) were observed in average weights between single wethers and single ewes but there were no differences in twins. However, lambs born and raised as singles had significantly ($p < .01$) heavier body weights than twins in both sexes. It is interesting to note that a test of homogeneity (17) between the regressions of body weight on age for the

TABLE 2.—WOOL AND BODY GROWTH DURING THE FIRST 14 MONTHS OF LIFE

	Standard errors			Regression equation	
	Sby1.2	Sby2.1	Sa	$\hat{Y}=a+b_1X+b_2X^2$	R^2
Age and Body Weight					
Male singles	.0471	.000096	1.1872	$\hat{Y}=23.82+.3359X-.000240X^2$	.9748
Male twins	.0755	.000150	1.8155	$\hat{Y}=15.66+.2858X-.000126X^2$	.9432
Female singles	.0392	.000081	0.9946	$\hat{Y}=26.25+.3242X-.000283X^2$	.9756
Female twins	.0578	.000118	1.4438	$\hat{Y}=14.62+.2856X-.000162X^2$	.9564
Combined	.0412	.000084	1.0348	$\hat{Y}=22.26+.3166X-.000228X^2$	.9778
Age and Clean Fleece Weight					
Male singles	.0022	.000005	0.0568	$\hat{Y}=-0.13+.0102X+.000017X^2$	.9914
Male twins	.0032	.000006	0.0782	$\hat{Y}=-0.51+.0121X+.000007X^2$	.9772
Female singles	.0017	.000004	0.0438	$\hat{Y}=-0.25+.0136X+.000009X^2$	.9663
Female twins	.0020	.000004	0.1578	$\hat{Y}=-0.31+.0096X+.000014X^2$	.9911
Combined	.0016	.000003	0.0396	$\hat{Y}=-0.42+.0135X+.000008X^2$	.9952
Age and Staple Length					
Male singles	.0316	.000064	0.7968	$\hat{Y}=6.99+.2991X-.000064X^2$	.9921
Male twins	.0604	.000120	1.4519	$\hat{Y}=-7.01+.4296X-.000370X^2$	.9698
Female singles	.0387	.000079	0.9813	$\hat{Y}=2.90+.3720X-.000210X^2$	.9881
Female twins	.0268	.000055	0.6711	$\hat{Y}=2.03+.3778X-.000271X^2$	.9932
Combined	.0216	.000044	0.5428	$\hat{Y}=2.04+.3652X-.000215X^2$	.9961

Age and Cross-section Area

	Sy	Sby.x	Sa	$\hat{Y}=a+bX$	
Male singles	48.755	.1092	13.0361	$\hat{Y}=380.05+.532763X$	
Male twins	47.128	.1063	12.6011	$\hat{Y}=352.62+.500440X$	
Female singles	35.553	.0804	9.5062	$\hat{Y}=381.52+.586716X$	
Female twins	37.376	.0858	9.9936	$\hat{Y}=338.40+.631139X$	
Combined	25.846	.0582	6.9111	$\hat{Y}=375.34+.538763X$	

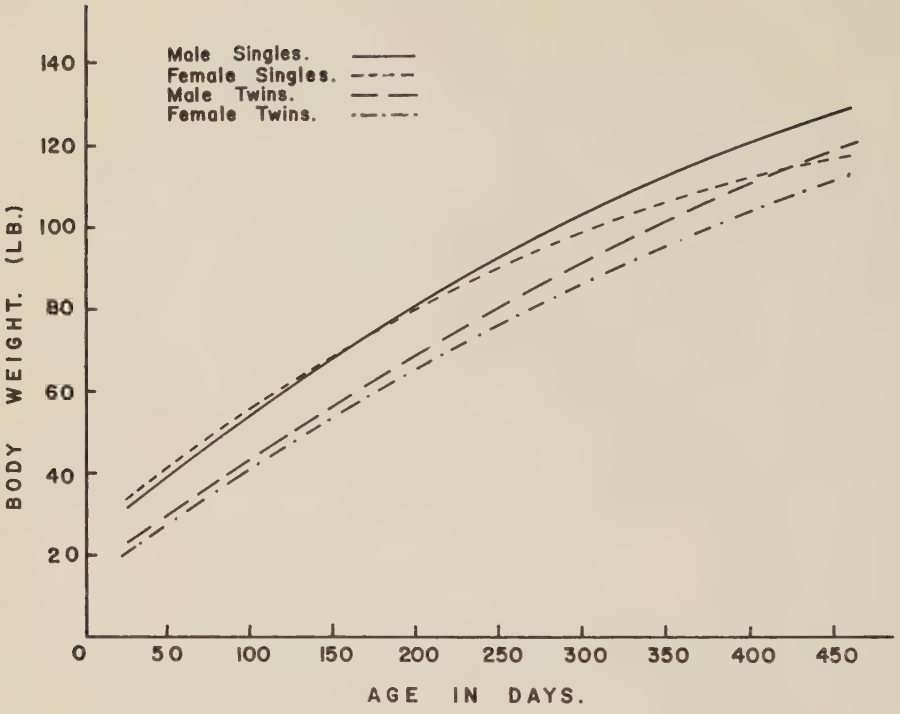

FIGURE 2. The relationship of body weight to age in young sheep.

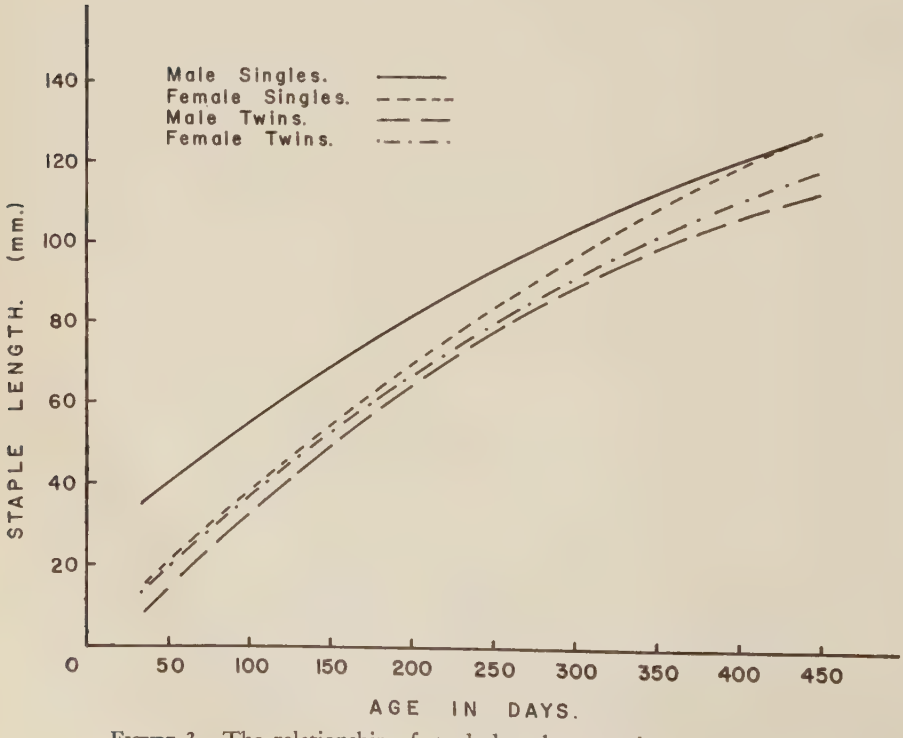

FIGURE 3. The relationship of staple length to age in young sheep.

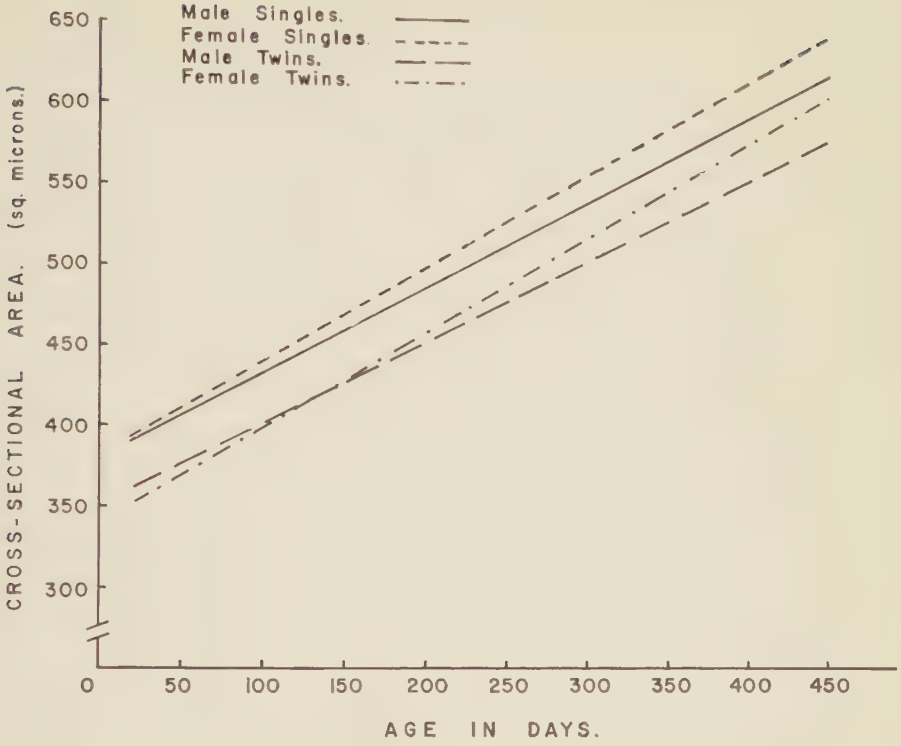

FIGURE 4. The relationship of cross-sectional area to age in young sheep.

four groups (single wethers, single ewes, twin wethers, and twin ewes) showed no differences. The mean square associated with the variation of the lot regressions was tested for significance using the mean square of the deviations from the individual lot regressions as the error term. These results would indicate that the rates of gains were essentially the same for singles and twins and that the absolute weight differences were maintained from 2 to 14 months of age. These weight differences were reflected in the periodic clean fleece weights and, with the exception of the single wethers, in the cross-sectional areas.

These results are in general agreement with the findings of Guyer and Dyer (9). Their results showed that, although singles gained at a faster rate from birth to 8 weeks of age, the gains were practically the same between 8 and 16 weeks of age. Apparently singles and twins exhibited the same potential for growth, although that of twin lambs was somewhat retarded during intra-uterine life and during the first weeks when milk constituted the main source of nutrients.

Staple Length-Age Relationship

The measurements on periodic wool samples indicated that the growth rate of the wool decreased slightly with advancing age (Figure 1). A test

of deviation from linear regression, applied to all the data, indicated that the deviations from a straight line were significant ($p < .01$). Subsequently, a parabola was found to be the best fitting curve for these data. The resulting lot regressions based on type of birth and sex are shown in Figure 3.

Differences in staple length at birth were small but increased gradually with advancing age. Females grew somewhat longer staples than wethers, this difference being significant ($p < .01$) for the singles after 300 days of age. However, a test of homogeneity showed no significant differences among lot regressions.

Type of birth appeared to be even more important than sex in influencing longitudinal growth of wool. The adjusted mean staple lengths were greater in singles than in twins ($p < .05$ for wethers and $p < .01$ for females). In addition staple length increased at a significantly ($p < .05$) faster rate in singles than in twins.

When analysis of covariance was used to control body weight, it was found that the staple length differences were independent. Although body weights were lower in females as well as in twins, indicating slower growth in these groups, staple lengths were found to be longer. Evidently the length of the staple cannot be considered as a simple expression of the general condition of the sheep but rather as being subject to both its nutritional and hormonal status.

Fibre Thickness-Age Relationship

Fibre thickness is known to increase rapidly after birth and reach constancy asymptotically (12). A similar trend was exhibited in these data. However, it was evident that the relationship within the period under study could be reduced to a straight line if the cross-sectional area was calculated and plotted against age. These regressions are shown in Figure 4.

It was pointed out previously that the fibre thickness determinations were made on the mid-portion of each staple and, consequently, these data should be considered as representing measurements up to 7 months of growth rather than to 14 months. Differences due to sex were small at birth and tended to diminish up to 100 days of age. From then on the coarsening was somewhat more pronounced in females than in wethers. However, statistical analysis indicated no significant differences among adjusted lot means and regressions. This also was true for the birth-type groups. Because of this, the data were combined and a further analysis made. This indicated that singles produced significantly coarser wool ($p < .05$) than twins but there were no differences between sexes, nor were the rates of increase different in any of the groups. Analysis of covariance to control body weight indicated that these differences still were evident. These results are in general agreement with those of Belič (1, 2).

Clean Fleece Weight-Age Relationship

The linear dependence of cross-sectional area on age and the slightly decreasing rate of longitudinal growth would, in themselves, define a declining rate of wool production. Instead, clean wool production exhibited a gradual increase on the basis of the data in Table 1. However, the rate

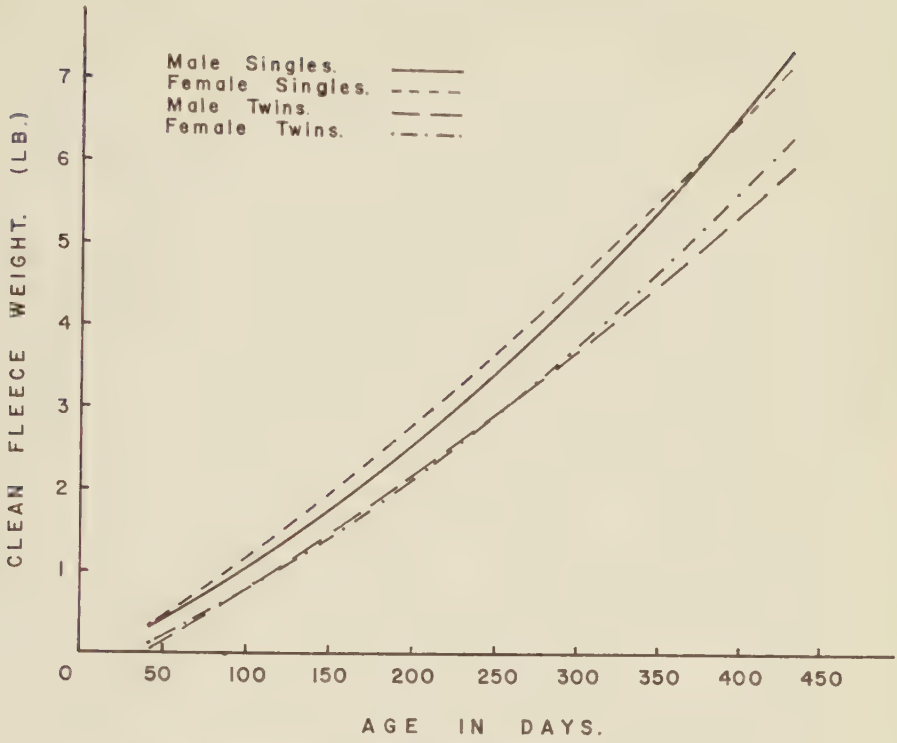

FIGURE 5. The relationship of clean fleece weight to age in young sheep.

of increase in weight declined as the sheep became older (Figure 1). Test of linearity (17) indicated that the deviations from the straight line were significant ($p < .01$). Because of this, the relationship within each lot was best expressed as a quadratic function. The resulting curves are shown in Figure 5.

The adjusted average clean fleece weights did not differ significantly between sexes in single lambs, but in the twins the females were significantly heavier ($p < .05$) than the wethers. The regressions of fleece weight on age were homogeneous, indicating that the rate of increase was uniform in both wethers and ewes, although somewhat lower in the latter. On the other hand, the differences in adjusted means and regressions were highly significant between singles and twins. Singles had heavier fleeces and the rate of increase was greater than in twins. Analysis of covariance showed that these differences existed when body weight was controlled.

The regression equations that were used to plot the average curves of Figure 5 may be used for estimating clean fleece weights. The reliability of such estimates, however, would be relatively low, as indicated by the adjusted standard errors of estimates, which ranged from ± 0.56 to ± 0.69 pounds in the various lots. In view of this, estimates were made by means of a linear model instead of a curvilinear one to determine whether there was any appreciable loss in precision. Since the sex regressions were homo-

geneous, the data within birth-type groups were pooled. The adjusted standard errors of estimates for curvilinear relationship were ± 0.56 and ± 0.63 pounds for singles and twins, respectively. These values were 0.59 pound in singles and 0.62 pound in twins when the deviations were measured from the straight line. Obviously there was no appreciable change in precision when a simple linear model was employed for estimating clean fleece weights.

It is evident that body weight, staple length, fibre thickness, and clean fleece weight vary with age, sex, and type of birth. In order to develop an estimating equation for clean fleece weight, it will be necessary to determine the interrelationship of these characteristics. The influence of other factors such as nutrition, breed, and environment on the characteristics examined would merit study so that a general estimating equation could be developed for clean fleece weight.

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ENERGY DIGESTIBILITY AND NITROGEN RETENTION BY PIGS AND RATS FED DIETS CONTAINING NON-NUTRITIVE DILUENTS AND VARYING IN PROTEIN LEVEL[1]

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ABSTRACT

Diets containing gross energy levels of 3.9 and 3.2 Cal./gm. and crude protein levels of 14 and 18 per cent on an air-dry basis (4.4 and 3.5 Cal./gm. and 15 and 20 per cent respectively on an oven-dry basis) were fed in a 2 x 2 factorial design to weanling rats and pigs. The lower energy level was achieved by adding 20 per cent of a fine aggregate of vermiculite. In the rat experiment the vermiculite was compared with a similar level of non-nutritive cellulose. Dry matter, apparent energy and apparent nitrogen digestibility and nitrogen retention were determined with 4- to 5-week-old rats weighing approximately 80 grams and with pigs averaging approximately 8, 20 and 50 kilograms liveweight.

The apparent digestibility of energy and nitrogen by rats and pigs was similar. The percentage apparent nitrogen digestibility was reduced in both species fed lower energy diets. Dry matter and energy digestibilities were lowered in rats fed lower energy diets containing vermiculite but a similar effect was evident only in 8-kilogram pigs.

Nitrogen retention varied between the two species. Percentage gross or digestible nitrogen retention in rats was increased with higher energy and with lower protein diets. Retention of digested nitrogen in pigs was reduced with higher energy compared to lower energy diets. Higher protein improved nitrogen retention in 8-kilogram pigs but lowered retention in heavier pigs.

INTRODUCTION

The species and age of an animal to which a diet is fed, as well as the caloric and protein content of the diet, may influence the utilization of energy and nitrogen (N)[3] in the diet as well as the rate of gain, food conversion and carcass characteristics of the animal. Bell and Loosli (3), Mitchell and Hamilton (9), and Reber *et al.* (11) are among those who have observed that the age and/or weight of a pig have an influence on biological value of a protein and on N retention in the animal. In a more recent report, Lloyd and Crampton (8) observed that increasing the percentage of protein or decreasing the percentage of crude fibre in a ration had a tendency to increase the apparent digestibility of protein.

In studies with rats Sibbald *et al.* (13) have shown that the percentage of N retained is highly correlated with the ratio of ADN to ADE in the diet. These workers also reviewed studies with other species where similar observations have been made.

Energy intake may be reduced in two ways: by lowering the caloric content of the diet or by restricting the amount of food which an animal is allowed to consume. To lower the ADE content of a diet a diluent may be used. Sibbald *et al.* (12) have used non-nutritive cellulose for this purpose in rat studies and Mraz *et al.* (10) have used sand and vermiculite in poultry studies.

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[3]The following abbreviations will be used: N = nitrogen, ADE = apparent digestible energy, ADN = apparent digestible nitrogen, DMD = dry matter digestibility, LE = lower energy, HE = higher energy, LP = lower protein and HP = higher protein.

TABLE 1.—DIETARY ALLOTMENT OF PIGS AND RATS

Diet no.	Diet	Diluent used
1	High energy-high protein (HE-HP)	None
2	High energy-low protein (HE-LP)	None
3	Low energy-high protein (LE-HP)	Terralite[1]
4	Low energy-low protein (LE-LP)	Terralite[1]
5	Low energy-high protein (LE-HP)	Alphacel[2]
6	Low energy-low protein (LE-LP)	Alphacel[2]

[1]Terralite—Purchased from Insulation Industries (Edmonton) Ltd. Terralite is a fine aggregate of vermiculite, which is an expanded or exfoliated mica. As analysed by Vermiculite Institute, Chicago, Ill., the product is relatively inert chemically but has a water-holding capacity of 300 per cent of its weight.
[2]Alphacel — A non-nutritive cellulose prepared by the Nutritional Biochemicals Corp., Cleveland, Ohio.

TABLE 2.—PERCENTAGE COMPOSITION OF DIETS ON AN AIR-DRY BASIS

Diet no. Energy-protein Diluent	1 HE-HP None	2 HE-LP None	3 LE-HP Terralite	4 LE-LP Terralite	5 LE-HP Alphacel	6 LE-LP Alphacel
Wheat	53.5	63.1	32.8	42.8	32.8	42.8
Corn	17.0	17.0	13.6	13.6	13.6	13.6
Sucrose	10.0	10.0	8.0	8.0	8.0	8.0
Fishmeal (72%)	4.5	2.1	6.1	3.6	6.1	3.6
Soybean oil meal (44%)	13.5	6.3	18.3	10.8	18.3	10.8
Ground limestone	0.6	0.6	0.48	0.48	0.48	0.48
Iodized salt	0.5	0.5	0.4	0.4	0.4	0.4
Vitamin mix[1]	0.3	0.3	0.24	0.24	0.24	0.24
Antibiotic supplement[2]	0.1	0.1	0.08	0.08	0.08	0.08
Terralite	—	—	20.0	20.0	—	—
Alphacel	—	—	—	—	20.0	20.0
Kilograms	100	100	100	100	100	100
Diet used in digestibility studies						
Crude protein, %	18.1	13.7	17.6	14.7	17.0	14.0
Gross energy Cal./gm.	3.93	3.91	3.25	3.25	3.99	3.94
Moisture, %	10	10	8	8	9	9
Average analysis of all diets						
Av. crude protein, %	17.9	13.6	17.9	14.0	—	—
Calculated total digestible nutrients, %	80.3	81.0	63.5	64.2	—	—

[1]In the HE-HP and HE-LP diet the following levels of vitamins were supplied per kilogram of ration:

Vitamin A	1100 I.U.
Vitamin D_2	220 I.U.
Choline	44 mg.
Niacin	40 mg.
Pantothenic acid	18 mg.
Riboflavin	9 mg.
Folic acid	264 micrograms
Vitamin B_{12}	20 micrograms

In the LE-LP and LE-HP diets these levels were reduced by 20 per cent on the assumption that animals fed these diets would eat more feed for an equivalent amount of gain.

[2]The antibiotic supplements supplied 11 mg. aureomycin hydrochloride, 5.5 mg. penicillin G procaine and 16.5 mg. streptomycin per kg. of HE diet (30 mg. antibiotic per ton).

The experiments to be reported were conducted to obtain information on the effect that diets differing in energy and protein level have on energy and N digestibility and N retention in pigs from 8 to 50 kilograms in liveweight. Trials with weanling albino rats were designed to obtain preliminary data on the relative effects when non-nutritive cellulose (Alphacel)

TABLE 3.—COMPOSITION OF DIETS ON AN OVEN-DRY BASIS

Diet no. Energy-protein	1 HE-HP	2 HE-LP	3 LE-HP	4 LE-LP	5 LE-HP	6 LE-LP
Terralite[1]	—	—	21.70	21.70	—	—
Alphacel[1]	—	—	—	—	20.90	20.90
Average crude protein %	20.10	15.20	19.10	16.00	18.60	15.40
Gross energy Cal./gm.	4.37	4.34	3.53	3.53	4.38	4.33
Gross energy less energy from diluent[2] Cal./gm.	4.37	4.34	3.42	3.42	3.46	3.42

[1]Terralite was found to be moisture free, while Alphacel contained 5 per cent moisture.
[2]The gross energy content of Alphacel was reported to be 420 Cal./100 gm. (5). Based on the decrease in energy due to the presence of Terralite in the diet the gross energy content of Terralite was calculated to be approximately 50 Cal./100 gm. Direct calorimetric determinations of the energy value of Terralite could not be made. In the production of Terralite, organic flotation agents are used which may not be completely burned off in the expansion of the vermiculite ore.

and a fine aggregate of vermiculite (Terralite) were used as diluents to lower the ADE content of a diet. The experiments also supplied information on the comparative results from digestibility and retention studies with the two species, pigs and rats.

FORMULATION OF EXPERIMENTAL DIETS

Rations fed to market pigs are generally reduced in protein and to a lesser extent in energy levels as the pigs grow heavier (2) in order to economically meet the nutrient requirements of the animals. In the experiments to be reported a constant ration was fed for the entire experimental period to get more specific data on energy and protein relationships and to allow a clearer interpretation of the results. The formulation and composition of the diets on an air-dry basis are given in Table 2. In Table 3 the composition of the oven-dry diets is reported as all metabolism data are presented on this basis.

Terralite was used to lower the ADE content of the diets. The suitability of Terralite for this purpose was determined by comparing it with Alphacel, which has been successfully used in rat studies by Sibbald *et al.* (12). As outlined in Tables 1 and 2, the weanling rats received the same diets, numbers 1 to 4, that were fed to the pigs, and in addition received LE diets 5 and 6 in which Alphacel replaced Terralite as a diluent. Diets fed to the rats were ground through a No. 50 screen in a Weber Pulverizing Mill to prevent the rats from sorting their food.

In making alterations in the gross energy and/or N levels of the diets, adjustments were made in the other nutrients to compensate for the change in food intake expected to occur when energy levels of a diet are altered (13).

METHODS AND PROCEDURES IN THE RAT EXPERIMENT

Twenty-four male weanling rats, 21 days of age, from the Department of Animal Science, University of Alberta, colony of the Sprague-Dawley strain were allotted to individual cages. There were 6 rats per row, representing the six diets used, in four different rows of a rack of cages. Rats from the same litter were placed in the same row, and hence the effect of row and litters are confounded. Following the method described by Sibbald *et al.*

TABLE 4. — RAT METABOLISM EXPERIMENT — AVERAGE BODY WEIGHTS AND FOOD CONSUMPTION, AVERAGE DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY, AND NITROGEN RETENTION, AND THE MEAN SQUARES OF THESE VALUES

		Gain in weight			Per 100-gm. body weight				Digestibility			Corr. digest.		Retention	
	No. rats	Acclim. period gm.	Metab. period gm.	Av. body weight metab. period gm.	Gain in metab. period gm.	A.D.E. consump. Cal.	Gross N consump. mg.	Oven-dry food per gm. gain gm.	Dry matter %	Energy %	Nitrogen %	Dry matter %	Energy %	Gross N %	ADN %
Diets															
HEHP	4	33	39	88	45	363	3044	2.2	86	88	88	86	88	53	60
HELP	4	24	34	77	44	413	2648	2.5	87	87	86	87	87	52	60
LEHP (Terralite)	4	25	32	78	41	344	3642	3.1	63	82	80	82	84	41	52
LELP (Terralite)	4	20	28	70	39	343	3031	3.4	66	82	80	85	85	44	56
LEHP (Alphacel)	4	31	34	83	40	341	3298	2.9	67	70	84	85	88	40	48
LELP (Alphacel)	4	28	32	80	41	340	2930	2.9	69	71	84	87	88	51	61
Diluents															
No diluent HE	8	28	36	83	44	388	2846	2.4	86	88	87	86	88	52	60
Terralite LE	8	22	30	74	40	344	3336	3.2	64	82	80	84	84	42	54
Alphacel LE	8	30	33	81	40	340	3014	2.9	68	70	84	86	88	46	54
Protein															
High Protein	12	30	35	83	42	349	3328	2.7	72	80	84	84	87	45	53
Low Protein	12	24	31	76	41	366	2803	2.9	74	80	83	86	87	49	59
Rows															
1	6	28	38	83	46	363	3154	2.5	72	79	83	84	86	48	58
2	6	25	36	79	47	358	3125	2.4	72	79	83	84	86	47	57
3	6	27	28	75	38	351	2976	3.0	74	81	84	86	88	47	56
4	6	28	29	80	36	358	3007	3.4	74	81	85	86	88	46	54
Source of variance	d.f.														
Total	23														
Diet	5			148**	17	3274	541**	0.8			46**	14**	12**	130**	111**
Diluent	2			177**	37	5693	497*	1.8			113*	23**	29**	207**	101*
Protein	1			321**	2	1607	1655**	0.2			3	21*	1	100**	191**
D X P	2			32	4	1689	26	0.1			1	3	1	69*	82*
Row	3			62	177	147	46	1.3			7	10*	6*	5	20
Error	15			26	125	1724	129	0.6			4	2	1	11	18

*Significant at $P < 0.05$
**Significant at $P < 0.01$

(13), the weanling rats were fed *ad libitum* the experimental diets to which they had been allotted, plus supplemental vitamins A and D. After a diet acclimatization period of 7 days, the rats were placed in metabolism cages using the same order of position and row in the cages as for the acclimatization period. Collection of feces and urine and the determination of ADE, ADN and N retention were as previously described by Hussar and Bowland (7) and Sibbald *et al.* (12).

METHODS AND PROCEDURES IN THE PIG EXPERIMENTS

Energy and N digestibility and N retention data were obtained for 16 male pigs at an average of 8-, 20- and 50-kilogram liveweight. The pigs were half-sib Landrace-Yorkshire crossbreds averaging 5.5 kilograms in weight at 3 to 4 weeks of age when they were randomly allotted to the four rations used in the trials. General management of the pigs, the conducting of the metabolism trials, the determination of the energy contents of the feed and feces and the N contents of the feed, feces and urine were similar to those reported by Hussar and Bowland (7).

Information on rate of gain and efficiency of feed utilization from weaning to market weight and on the carcass characteristics of the pigs are reported in Tables 7 and 8. In a subsequent paper a detailed report will be given of the performance of four strains of pigs of both sexes fed the same rations as were used in this study.

RESULTS AND DISCUSSION

Rat Data

A summary of the results obtained in the rat experiment and the mean squares obtained by analysis of variance are given in Table 4.

Average Body Weight, Rate of Gain, Energy and Nitrogen Consumption and Efficiency of Food Utilization

The average rat weight on each diet at the beginning of the acclimatization period was 36 ± 1 grams. Rats on LP or on Terralite diets during acclimatization gained slowly and therefore weighed less than the other rats during the metabolism period. To adjust for the weight differences, average weekly gain as well as food, ADE and gross N consumption during the metabolism period were compared on a 100-gram body weight basis. Neither of the two diluents nor the protein level influenced any of these factors other than the gross N consumption. This latter result was to be expected from the design of the experiment. A difference in gross N consumption between diluents also resulted as rats fed the Terralite diets consumed more nitrogen than those fed the control diets or the Alphacel diets. Although the intake was not significantly changed, rats on the HE-LP diet consumed a higher level of ADE than those fed other diets, an observation similar to that reported by Bowland *et al.* (5) in studies on fat and N levels in rat diets.

Digestibility of Dry Matter and Energy

Dry matter and energy digestibility values were corrected for the moisture content and presence of a diluent in the diet. DMD and ADE

TABLE 5. — PIG METABOLISM EXPERIMENTS — BODY WEIGHT, FEED CONSUMPTION; DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

Diet	No. pigs	Gain in weight kg.	Av. body weight kg.	Per 100-gm. body weight			Oven-dry food per kg. gain kg.	Digestibility			Corr. digest.		Retention	
				Av. 5-day gain gm.	ADE consump. Cal.	Gross N consump. mg.		Dry matter %	Energy %	Nitrogen %	Dry matter %	Energy %	Gross N %	ADN %
8-kg. period														
HEHP	4	1.2	9.3	12.7	95.1	629	1.7	89	88	89	89	88	55	62
HELP	4	0.8	8.2	9.6	96.1	485	2.3	90	89	86	90	89	42	48
LEHP	4	1.0	7.8	13.3	86.7	690	1.8	67	81	78	87	85	50	64
LELP	4	0.9	7.7	11.7	82.0	548	2.0	70	83	79	90	87	49	62
20-kg. period														
HEHP	4	2.7	23.4	11.5	112.6	745	2.2	87	86	84	87	86	48	57
HELP	4	2.4	20.4	11.4	132.4	668	2.7	84	84	77	84	84	46	60
LEHP	4	2.2	20.4	10.6	101.3	807	2.7	68	80	76	87	83	49	64
LELP	4	1.3	19.4	6.5	99.9	668	4.4	66	82	76	85	85	53	70
50-kg. period														
HEHP	4	4.4	49.0	8.9	97.8	647	2.5	89	89	88	89	89	35	39
HELP	3	4.7	56.3	8.2	88.1	445	2.5	89	89	87	89	89	38	44
LEHP	3	3.3	49.1	8.8	91.1	725	2.9	72	84	83	91	87	43	53
LELP	4	4.3	49.2	8.7	92.0	615	3.0	70	85	82	89	88	45	54

remained the same in the presence of Alphacel as on the HE diets but decreased in the presence of Terralite. Dry matter digestibility was also lower with HP rations.

The coefficients of digestibility for DM and energy were higher for rats in the two bottom rows of the metabolism rack as compared with rats in the two top rows. As the temperature of the top row was only 0.4°C. higher than that of the bottom row, and as other factors were apparently equal, the differences in digestibility may have been associated with between litter variation. In previous digestibility studies with rats from this colony, there has been no evidence of litter variation.

Digestibility of Nitrogen

The percentage ADN tended to be increased in HP diets. In earlier work, Bowland *et al.* (5), reporting on the influence of dietary fat, found that the percentage ADN increased as N levels in the diet increased, whereas Forbes *et al.* (6) found that the true digestibility of peanut and egg protein and casein was not influenced by protein concentration in the diet. These reports are not necessarily at variance as one deals with apparent digestibility and one with true digestibility. In all such studies care must be taken in interpretation of results of apparent digestibility as they may relate to true digestibility.

A decrease in percentage ADN occurred when a diluent was used to lower the ADE content of the diet. This observation agrees with that of Sibbald *et al.* (13) and others who have noted that increasing the levels of non-nutritive or fibrous material tended to decrease the apparent digestibility of the N of the food. Several workers, e.g., Whiting and Bezeau (14), have reported decreased protein digestibility along with increased metabolic fecal nitrogen (M.F.N.) in the pig when the fibre content of the ration was increased. The difference in ADN noted between LE rations containing Alphacel and those containing Terralite could be accounted for if it is assumed that Terralite increased M.F.N. to a greater degree than Alphacel.

Nitrogen Retention

Diets fed in this experiment had energy-nitrogen ratios below 277 Cal. ADE per gram ADN reported by Sibbald *et al.* (13) as being optimal for maximum nitrogen retention in 4- to 5-week-old rats. Possibly as a result of this ratio N retention as a percentage of gross or digestible N was low on all diets. A difference in retention between the HP and LP diets, however, indicated that nitrogen was used less efficiently as the protein level was increased, an observation which agrees with several studies previously reported, for example Bowland *et al.* (5), and Sibbald *et al.* (13).

Retention of N as a percentage of gross or digestible nitrogen was lower for LE diets than for HE diets. The percentage of gross N retained was also lower for diets containing Terralite than for those containing Alphacel. The latter result occurred because of reduced digestibility in diets containing Terralite. The interaction in N retention between diluent and protein is probably associated with diet 5, the LE-LP Alphacel diet, where N retention was not lowered in comparison with HE diets. No other interactions of significance appeared in the rat study.

TABLE 6. — MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE FOR PIG METABOLISM EXPERIMENTS

			Per 100-gm. body weight				Corr. digest		Retention	
	d.f.	Av. body weight	Av. 5-day gain	A D E cons.	Gross N cons.	Digestibility of nitrogen	Dry matter	Energy	Gross N	A D N
8-kg. period										
Total	15									
Ration	3	2.1*	10.7	184	32,404*	103.1**	9.9	12.4*	116.2*	200**
Energy	1	3.8*	7.9	507	15,457	296.0**	7.2	29.6**	6.6	235**
Protein	1	1.4	22.0	14	81,752**	2.3	12.4	4.7	203.1**	247**
E x P	1	1.1	2.3	33	4	11.0	10.2	2.9	138.7*	119*
Replicate	3	1.2	19.9	142	6,553	14.8	25.7*	11.1*	3.4	5
Error	9	0.5	12.6	142	6,510	4.4	4.6	2.2	16.8	16
20-kg. period										
Total	15									
Ration	3	12.1**	22.3	902	17,989**	68.3**	7.2*	6.7	35.6	133.9
Energy	1	16.3**	33.7	1902**	3,772	91.6**	0.7	3.9	61.4	302.0*
Protein	1	16.3**	17.2	337*	43,368**	66.8**	19.7**	0.4	7.7	89.1
E x P	1	3.8	16.0	449*	3,828	46.4**	1.1	15.9*	37.9	10.6
Replicate	3	15.3**	5.1	178	7,537	29.5**	11.0**	10.4*	82.4	72.0
Error	9	1.2	8.9	50	2,346	2.8	1.5	2.4	27.0	45.2
50-kg. period										
Total	13									
Ration	3	39.6*	3.8	69.3	39**	39.1*	3.4	2.2	77.9	188.5
Energy	1	25.6	2.4	30.9	31**	115.8**	4.9	4.5	213.2	530.9*
Protein	1	32.0	1.3	46.9	60**	6.4	1.6	0.6	39.4	75.5
E x P	1	61.2*	7.8	130.1	25**	−4.9	3.7	1.4	−19.0	−40.9
Replicate	3	15.8	3.6	119.3*	6*	0.5	3.2	0.5	15.0	21.9
Error	7	7.9	5.5	27.0	1	7.4	3.1	3.4	44.9	62.7

*Significant at $P < 0.05$
**Significant at $P < 0.01$

Pig Data

The data for 8-, 20- and 50-kilogram pigs are reported in Table 5, and the mean squares from analysis of variance of these data are in Table 6. To adjust for weight differences in each series of metabolism studies, average 5-day gain, ADE and gross N consumption were converted to a 100-gram body weight basis.

Average Body Weight, Rate of Gain, ADE Consumption and Feed Conversion

Average 5-day gain per 100-gram body weight was generally higher for pigs on HE and HP rations. The data in Table 7 summarize the rate of gain for the pigs from weaning to market weight and these gains agree with the short-term results obtained while the pigs were in metabolism crates.

ADE consumption was higher for 8- and 20-kilogram pigs fed HE rations than for those fed LE rations, with the difference being significant at the 20-kilogram weight. Energy levels of the rations had no influence on ADE consumption in 50-kilogram pigs.

Protein content of the rations also influenced ADE consumption. Twenty-kilogram pigs, responding in a manner similar to the rat, consumed greater amounts of ADE when fed the HE-LP ration. This same trend was not significant in 8-kilogram pigs which had been fed the ration for only 10 to 14 days and it was not evident in 50-kilogram pigs which would be expected to require less N per unit of feed or of energy.

In the 8-kilogram, as well as in the 20-kilogram pigs for which the interaction was significant, there was a greater increase in ADE consumption when the energy content of LP rations was increased than when the energy content of HP rations was increased. This suggests that young pigs may have consumed greater amounts of ADE as an indirect result of the attempt to obtain more protein.

TABLE 7.—AVERAGE DAILY LIVEWEIGHT GAIN AND EFFICIENCY OF FEED UTILIZATION OF PIGS FROM WEANING TO MARKET WEIGHT AND THE MEAN SQUARES OF THESE VALUES

Diet	No. of pigs[1]	Av. daily gain	Av. daily feed[1]	Feed per kg. gain[2]	ADE per kg. gain
		kg.	kg.	kg.	therms
1 HE-HP	4	0.64	1.6	2.5	9.5
2 HE-LP	3	0.59	1.5	2.5	9.5
3 LE-HP	3	0.55	1.3	2.4	9.0
4 LE-LP	3	0.55	1.4	2.5	9.5
Source of variances	d.f.				
Total	12				
Ration	3	0.06	0.37	0.01	0.04
Energy	1	0.16	0.01	0.00	0.05
Protein	1	0.02	0.06	0.01	0.03
E x P	1	0.00	1.04	0.00	0.05
Replicate	3	0.02	0.13	0.05	0.17*
Error	6	−0.00[3]	−0.01[3]	0.01	0.03

[1]One of the four pigs in each of diets 2, 3, and 4 died before reaching market weight.
[2]Oven-dry feed less diluent.
[3]A negative mean square for error, resulting from an unequal number of pigs in rations and replicates, prevented a test of significance from being carried out for average daily gain and daily feed.
*Significant at $P < 0.05$

TABLE 8. — AVERAGE RECORD OF PERFORMANCE MEASUREMENTS AND SCORES FOR PIG CARCASSES AND THE MEAN SQUARES OF THESE VALUES

Diet	No. of pigs[1]	Live market weight lb.	Hot dressed weight lb.	Dressing percentage %	Length of side in.	Av. fat; shldr., back and loin in.	Area of loin sq. in.	Total R.O.P. score %
HE-HP	4	198	160	81	30.1	1.5	4.18	73
HE-LP	3	200	159	79	30.3	1.5	3.52	71
LE-HP	3	196	146	74	30.3	1.1	3.82	88
LE-LP	3	195	148	76	30.4	1.4	3.97	82
Source of variance	d.f.							
Total	12							
Ration	3	21	171*	26.4	0.06	0.08**	0.27	209
Energy	1	54	499**	71.3**	0.07	0.11**	0.00	572*
Protein	1	0	0	0.2	0.07	0.05*	0.25	25
E X P	1	8	14	7.7	0.04	0.09*	0.54	31
Replicate	3	16	8	4.3	0.04	0.01	0.05	47
Error	6	34	20	2.9	0.34	0.01	0.33	57

[1]One of the four pigs in each of rations, 2, 3, and 4 died before reaching market weight.
*Significant at $P < 0.05$
**Significant at $P < 0.01$

Feed conversion figures for the 5-day metabolism periods varied rather widely. As shown in Table 7, for the entire experiment ADE intake per kilogram gain or feed intake per kilogram gain, corrected for non-nutrient diluent, did not vary appreciably from lot to lot.

Digestibility of Dry Matter and Energy

As in the rat experiment, the DM and ADE figures were adjusted for moisture and diluent content. In the 20- and 50-kilogram pigs the DMD and ADE were similar for LE and HE rations. The ADE was lowered when rations containing Terralite were fed to 8-kilogram pigs.

Dry matter and ADE coefficients were lower for 20-kilogram than for 8- or 50-kilogram pigs. There was also a difference between replicates in DMD and ADE in 8- and 20-kilogram pigs, possibly indicating between-litter variation, although the difference may have been associated with the rather wide variability of results in the pig experiments.

Digestibility of Nitrogen

The percentage ADN did not increase significantly as the N level in the diet increased, except for 20-kilogram pigs fed HEHP rations. The percentage ADN tended to be higher, however, when HP rations were fed to 8- and 50-kilogram pigs, so that the over-all results are very similar to those from the rat experiment. Also, as in the rat experiments, a decrease in percentage ADN occurred when diluted or LE rations were fed as compared to HE rations.

Nitrogen Retention

Increasing the protein level of both HE and LE rations lowered N retention by 50-kilogram pigs, while this effect on N retention occurred only in LE rations in 20-kilogram pigs. Although these differences were not significant they indicated a trend toward less efficient utilization of protein when 20- and 50-kilogram pigs were fed HP rations, an observation similar to that reported for pigs by Bell and Loosli (3), and Reber *et al.* (11) and to that found in the rat studies.

Based on either gross or digestible N retention there was an interaction between energy and protein levels in the rations of the 8-kilogram pigs. Nitrogen retention of the HE-HP ration (150 Cal. ADE/gm. ADN) was 13 to 14 per cent higher than that of the HE-LP ration (200 Cal. ADE/gm. ADN), whereas N retention of the LE-HP ration (128 Cal. ADE/gm. ADN) was only 1 to 2 per cent higher than that of the LE-LP ration (155 Cal. ADE/gm. ADN). In this study, N retention was lowered in 8-kilogram pigs when the energy to protein ratio was higher than 150 Cal. ADE/gm. ADN. However, feeding too high a level of protein in relation to energy would probably also lower N retention because of greater metabolic waste.

With all weights of pigs the percentage N retention on a gross N or ADN basis was higher for pigs fed LE as compared to HE rations.

Carcass Data

The carcass data for the pigs are summarized in Table 8. Increasing the energy level of the ration increased the hot dressed weight, dressing percentage, and the average backfat and decreased the Record of Performance score (1)*, whereas increasing the protein level of the ration affected only the backfat thickness. An interaction resulted as increasing the protein level of LE rations decreased backfat more than increasing the protein level of HE rations. Although the numbers of pigs in this study are too limited to make definite observations on carcass characteristics, the carcass measurements agree, in general, with those reported by Bowland and Berg (4) in energy-protein studies with pigs.

Comparison of Rat and Pig Data

Table 9 compares the ADE, ADN and gross N retention for 4- to 5-week-old 60- to 100-gram rats and for pigs at 8-, 20- and 50-kilogram liveweight. The digestion of energy and N by rats and pigs was similar, although more variation was noted with the pigs. The results suggest that the weanling rat could be used to obtain energy and N digestibility coefficients that could be transposed with little error in formulating rations for pigs.

*Scored by standards in effect in 1959

TABLE 9.—COMPARISON OF APPARENT DIGESTIBLE ENERGY AND NITROGEN AND NITROGEN RETENTION OF OVEN-DRY RATIONS FOR RATS AND PIGS

Diet no. Energy-protein Diluent	1 HE-HP None	2 HE-LP None	3 LE-HP Terralite	4 LE-LP Terralite
Gross energy Cal./100 gm. food	437	434	353	353
ADE Cal./100 gm. food				
Rats	383	379	288	291
Pigs 8-kg.	387	385	287	294
20-kg.	377	364	282	288
50-kg.	387	385	297	299
Mean	384	378	289	294
Gross nitrogen mg./100 gm. food	2892	2189	2811	2356
ADN mg./100 gm. food				
Rats	2548	1893	2252	1875
Pigs 8-kg.	2565	1889	2205	1869
20-kg.	2443	1685	2145	1781
50-kg.	2546	1907	2325	1928
Mean	2518	1827	2225	1859
ADE Cal./gm. ADN food				
Rats	150	200	128	155
Pigs 8-kg.	151	204	130	157
20-kg.	154	216	131	162
50-kg.	152	202	128	155
Mean	152	207	130	158
N retained mg./100 gm. food				
Rats	1529	1136	1171	1050
Pigs 8-kg.	1411	793	1103	916
20-kg.	1515	809	1373	1104
50-kg.	993	839	1232	1041
Mean	1346	814	1236	1020

There was less similarity between the N retention data obtained for weanling rats and for pigs, and it would seem impossible to transpose data from one species to another. This is particularly true as N retention was quite different in 8-, 20- and 50-kilogram pigs.

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DEVELOPMENT OF THE ROMNELET SHEEP[1]

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ABSTRACT

In 1935 the Canada Department of Agriculture undertook the development of a new breed of sheep at the Experimental Farm, Manyberries, Alberta. The foundation stock consisted of 15 Romney Marsh rams and 520 Rambouillet ewes, with introductions of 1 Targhee ram in 1942 and 6 Romeldale rams in 1944. Two of the Romeldale rams were used again in 1945. The flock has been closed to outside introductions since 1945 and the breed which resulted has been named "Romnelet".

Following the first cross, the F_1 animals were inter-mated and no backcrosses were made. A genealogical study up to, and including, 1955 showed the average annual size of the breeding flock to be 10 rams and 338 ewes and the average generation interval 3.5 years. On the average, there were 13 rams and 301 ewes selected per generation. The mean inbreeding coefficient of the 1955 lambs was 8 per cent.

Romnelets are polled, open-faced, free from skin wrinkles, with white face and legs and a fleece of $\frac{3}{8}$ or $\frac{1}{2}$ staple wool. Means and standard deviations of performance traits in the new breed under range conditions are reported.

INTRODUCTION

In 1935 the Canada Department of Agriculture undertook the development of a new breed of sheep at the Experimental Farm, Manyberries, Alberta, with Romney Marsh rams and Rambouillet ewes as foundation stock. The objectives were to develop a suitable breed of sheep for the range areas of western Canada, bearing in mind both climatic conditions and market requirements for wool and lamb, and to develop a white-faced breed that would be satisfactory to use for fat lamb production when crossed with mutton breeds under farm conditions (1).

As stated by Rasmussen (4), the Rambouillet of that day was not considered to have the carcass conformation, staple length and light shrinking fleece that were required for the most ready disposal of its products at favourable prices. The Rambouillet also was generally criticized for excessive face covering and neck wrinkles.

A commercial rancher, R. C. Harvey of Lethbridge, Alberta, had crossed Romney Marsh rams with Rambouillet ewes and developed a flock of sheep in the 1920's that showed considerable promise as a producer of lamb and wool. Unfortunately, his project was not carried far enough to fix a definite type before the disposal of his flock (4). The Manyberries project was initiated at the request of sheepmen who remembered the merits of the Harvey sheep. The resulting breed has been named "Romnelet".

The purpose of this paper is to report the history of the Romnelet, the breeding methods used, the genealogical aspects of breed development, and the breed characteristics. The genetic trends in performance and the role of selection will be reported in subsequent papers.

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[1]Contribution from the Research Branch, Canada Department of Agriculture, and adapted from a thesis submitted by the senior author to the Graduate Faculty, University of Minnesota, St. Paul, Minn., in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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FOUNDATION STOCK

Foundation stock for the Romnelet consisted of 15 purebred Romney Marsh rams that were imported from William Riddell, Monmouth, Oregon, and 520 grade Rambouillet ewes selected from the range flocks of Gilchrist Brothers and Peter Kirkvold of the Manyberries district. First-cross lambs were born in 1936, 1937 and 1938. A Targhee ram imported from the U.S. Western Sheep Breeding Laboratory, Dubois, Idaho, was used in the flock in 1942. In addition, six Romeldale rams were used for breeding in 1944 and two of these rams were used again in 1945. The Romeldales were imported from the flock of A. T. Spencer, Gerber, California, and were similar in genetic background to the Romnelets, being developed from the Romney X Rambouillet cross. With these exceptions, the flock was closed from the time of inter-mating of the first-cross generation.

No body weights were recorded on the foundation stock. Photographic records show that the Romney rams were uniformly open-faced, smooth and thick of body. Their fleeces were of longwool character and graded 44's and 46's (¼ blood). Over 90 per cent of the foundation ewe fleeces were in the finewool class. The wool was largely of short staple; 48 per cent of the fleeces fell into the "clothing" grades after the severe winter of 1936-37.

FLOCK MANAGEMENT

During the development of the Romnelet, the flock was maintained under range conditions. The range was native prairie, with speargrass (*Stipa comata*), Junegrass (*Koeleria cristata*), bluejoint (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), Sandberg's bluegrass (*Poa secunda*) and niggerwool (*Carex filifolia*) predominating. A few broad-leaved plants, particularly winterfat (*Eurotia lanata*), salt sage (*Atriplex Nuttallii*) and sagebrush (*Artemisia cana*), provided a limited amount of nutritious forage during the fall and winter months (Figure 1). The ewes were fed hay during the breeding season. During the remainder of the

FIGURE 1. Romnelet ewes on winter range at the Experimental Farm, Manyberries. Note clumps of sagebrush.

year they were dependent on grazing for their roughage, unless deep snow or blizzards prevented grazing. Some concentrates were fed to ewes during pregnancy as deemed necessary; in the later years this was confined mainly to the last third of the gestation period. Rams grazed during most of the year and received supplemental hay and grain during the winter when deep snow or blizzard conditions prevailed.

BREEDING METHODS

Flock mating was used to produce the first-cross lambs. Throughout the remainder of the project the ewes were pen-mated, with one ram to

TABLE 1.—NUMBERS OF LIVE MALE AND FEMALE LAMBS BORN 1936 TO 1953, PERCENTAGES SELECTED, PERCENTAGES CONTRIBUTING TO 1955 LAMB CROP AND PERCENTAGES OF SELECTED ANIMALS CONTRIBUTING

	Male	Female
Number of live lambs born	3,365	3,556
Number selected	76	1,716
Per cent selected	2.3	48.3
Number contributing to 1955 lambs	70	611
Per cent contributing to 1955 lambs	2.1	17.2
Per cent of selected animals contributing to 1955 lambs	92.1	35.6

TABLE 2.—LAMB PRODUCTION AND YEARLING TRAITS OF RANGE ROMNELETS BORN IN 1954 AND 1955 AT THE EXPERIMENTAL FARM, MANYBERRIES

	1954	1955	2 years	
			Mean	Pooled standard deviation[1]
Ewes bred that lambed, %	87.0	98.7	92.8	
No. of lambs per 100 ewes bred				
Alive at birth	109.6	130.4	120.0	
Weaned	95.0	110.6	102.8	
Lambings that were multiple, %	39.1	39.7	39.4	
Ewes lambed that weaned twins, %	21.3	24.1	22.7	
Live lambs born that were twins, %	46.0	58.6	52.3	
Lambs weaned that were twins, %	47.7	57.2	52.4	
Birth weight of lambs, lb.	9.1	9.8	9.4	1.6
Weaning weight of lambs, lb.	63.8	54.7	59.2	8.9
Age at weaning, days	100	116	108	
Yearling grease fleece weight, lb.				
Rams	11.0	9.6	10.3	1.1
Ewes	9.6	7.5	8.6	1.0
Yearling clean fleece weight, lb.				
Rams	6.2	4.9	5.6	0.6
Ewes	5.4	4.4	4.9	0.8
Yearling wool staple length, mm.				
Rams	109.1	102.9	106.0	10.5
Ewes	108.2	97.5	102.8	10.7
Yearling wool fibre thickness, microns				
Rams	28.2	26.3	27.2	2.0
Ewes	28.1	26.0	27.0	2.3
18-month weight of ewes, lb.	117.0	110.5	113.8	9.7

[1]Within year, type of birth or rearing (single or twin), age of dam (2, 3, 4-6, or over 6 years), and, for birth and weaning weights, within sex

each pen of ewes, so that complete pedigree records were available for the F_2 and succeeding generations.

Following the first cross, the F_1 animals were inter-mated and no back-crosses were made.

Lambing commenced early in April and continued for about 5 weeks. Within 24 hours after birth the lambs were weighed and ear-tagged for identification. Twins were retained when the dam appeared to have sufficient milk supply or when they could be fostered by another ewe that had lost her own lamb. In many instances lambs that were small or weak were discarded.

Ram lambs were weaned in August or early September. The remainder were weaned later in the fall, usually in early October. About two-thirds of the ram lambs and one-third of the ewe lambs were culled at weaning each year. Retention at that time was based on weaning weight, freedom from horns, freedom from wrinkling, open face, body conformation and apparent density of fleece.

A further culling was effected among rams and ewes during their second summer. Selection among yearlings was based on the following traits: body weight; body conformation, with major emphasis on thickness of fleshing; fleece weight; staple length; uniformity of fleece; and freedom from such defects as coarse wool, black spots, weak pasterns, overshot or undershot jaw and cryptorchidism.

There was a tendency to retain for breeding the rams that excelled in body weight, conformation and fleece weight, although some attention was given to average weaning weight and appearance of their progenies. In the later years, ewes were retained for breeding as long as they were productive in order to foster longevity in the flock. Percentages culled were 21, 20, 22, 32, 62, 84 and 100 for ewes at 2, 3, 4, 5, 6, 7 and 8 years of age, respectively. Culling of ewes was based on infertility, low weaning weight of offspring, defective udders, spreading teeth and emaciation.

GENEALOGY

As shown in Table 1, 2.3 per cent of the males recorded as being alive at birth were selected for breeding and 48.3 per cent of the females were selected. Over 90 per cent of the selected rams and about one-third of the selected ewes were contributors to the 1955 lamb crop.

The size of the breeding flock ranged from a maximum of 15 rams and 520 ewes in 1935 to 7 rams and 221 ewes in 1949, with an average of 10 rams and 338 ewes from 1935 to 1954.

The average generation interval over the period for which ages of parents at lambing were known (1938 to 1955, inclusive) was 3.5 years. Average ages at lambing were 3.2 and 3.6 years for sires and dams, respectively. From 1935 to 1955, there were, on the average, 13 rams and 301 ewes selected per generation.

The Targhee ram used for breeding in 1942 was a contributor to 14 per cent of the 1955 lambs, and the Romeldale rams used in 1944 and 1945 were contributors to 53 per cent of the 1955 lambs.

TABLE 3.—EFFECTS OF AGE ON THE WEANING WEIGHT AND YEARLING TRAITS OF RANGE ROMNELETS BORN IN 1954 AND 1955

	Regression, per day
Weaning weight[1], 1954	0.08 lb.
1955	0.46 lb.**
Grease fleece weight[1], rams	0.08 lb.**
ewes	0.01 lb.
Clean fleece weight[1], rams	0.03 lb.**
ewes	0.01 lb.
Staple length	0.21 mm.*
Fibre thickness	0.04 micron*
18-month weight of ewes	0.11 lb.*

*,**Significant ($P < 0.05$ and 0.01, respectively)
[1]Heterogeneity of regression between years or sexes significant ($P < 0.01$)

A study was made of the 1955 lamb crop to determine what effect the introductions of Targhee and Romeldale may have had on the performance of the breed. The 1955 descendants of the Romeldales and Targhee did not differ significantly from the other Romnelets in birth weight, weaning weight or clean fleece weight, but they had significantly ($P < 0.05$) higher post-weaning gain to 1 year of age. The weighted mean difference was 5 pounds. The descendants of the Romeldale rams exceeded those of the Targhee significantly ($P < 0.01$) in birth weight, but did not differ from them in weaning weight, post-weaning gain or clean fleece weight.

Inbreeding coefficients of the 1955 lambs, computed by the methods of Wright (9, 10), ranged from 0 to 26 per cent and averaged 8 per cent.

BREED CHARACTERISTICS

There was an immediate improvement in wool staple length after the first cross. Only 10 yearling ram fleeces and 10 yearling ewe fleeces sheared after 1937 were recorded as being of "short" staple or "clothing". Romnelet fleeces grade ⅜ or ½ staple and yield 55 to 60 per cent of clean wool.

During the period of breed development, there was a wide range in percentage of multiple lambings, with an average of 30 per cent. There was only 1 year after 1945 when the percentage of multiple lambings dropped below 38 per cent. The increase in twinning was probably environmental, as singles, rather than twins, were favoured in selection. Although 45 per cent of the lambs weaned were twins, only 27 per cent of the rams and 37 per cent of the ewes selected were twins.

It has been established that range ewes with open faces are superior to face-covered ewes in lamb production (7, 8). A study of the Romnelet lambs weaned in 1954 and 1955 showed that 80 per cent were open-faced and only 5 per cent had completely wool-covered faces.

Neck wrinkles were common in the foundation ewes but as a result of the breeding program wrinkling has been practically eliminated in the Romnelet.

FIGURE 2. Romnelets at the Experimental Farm, Manyberries, Alberta.
Upper left, breeding rams; *upper right,* ewes in full fleece; *lower left,* ewes just before lambing, *lower right,* weaned ewe lambs.

The Romney Marsh is a polled breed and the Rambouillet is generally horned in the male, although polled strains of the Rambouillet breed now are being developed. Romnelets were developed as a polled breed; less than 3 per cent of the male lambs weaned in 1954 and 1955 were recorded as having horns or scurs.

The appearance of Romnelet rams, ewes and lambs is illustrated in Figure 2.

Slen *et al.* (6) reported that Rambouillet sheep produced slightly more wool and heavier weanling lambs than Romnelets in a comparative study at the Scandia, Alberta, Substation from 1948 to 1951. There were no differences between the two breeds relative to average daily gain in the feedlot or efficiency of feed utilization, although the Romnelets had higher carcass grades. These findings were in close agreement with those of Rasmussen and Weir (5), who reported on feeding trials from 1937 to 1939 in which Romney X Rambouillet crossbreds were compared with Rambouillets.

The productivity of Romnelets under range conditions at Manyberries is indicated in Table 2. In computing pooled standard deviations, data on weaning weight and post-weaning traits were adjusted to the yearly average age, where intra-year, intra-sex regression analysis indicated significant age effects. The regression coefficients are given in Table 3.

From 1944 to 1947 eight test flocks of Romnelets were established in various parts of Canada in order to measure the usefulness of this breed under various environmental conditions (1). Pedigree records were maintained in some of these flocks. At present, there are five flocks of Romnelets in existence, in addition to the Experimental Farm flock, and all are located in Alberta.

DISCUSSION

Some information about the acceptability of the new breed was obtained from the test flocks. Ease of handling, mothering instinct, rustling ability, and good fleece weight were some of the advantages cited (2). One test flock operator was able to market Romnelet lambs directly off grass under central Alberta semi-range conditions. However, most test flock operators commented to the effect that Romnelet lambs mature more slowly than lambs of the Suffolk and Hampshire breeds. At the University of Alberta*, Romnelet lambs made satisfactory gains up to a weight of 90 pounds, whereas Suffolk and Hampshire lambs gained well up to 120 pounds. Romnelet ewes produced, on the average, 2 pounds more wool than ewes of the other two breeds. Under eastern Canadian conditions the Suffolk and Hampshire had a higher average lamb crop percentage than the Romnelet (3).

There was wide variation in productivity of test flocks from one location to another. Flock average fall body weights of Romnelet ewes ranged from 119 to 149 pounds; average grease fleece weights, 7 to 10 pounds; and weaned lamb crop percentage, based on number of ewes bred, 91 to 123 per cent.

*Bowstead, J. E., Department of Animal Science, University of Alberta, Edmonton, Alta. *Private communication.*

The Romnelet is well adapted to Canadian range conditions, and its greatest usefulness will probably be realized through the production of market hybrids in western Canada. It has potential, however, under either farm or range conditions. Some benefit could be expected from a cross of the Romnelet and Columbia or Corriedale breeds to obtain open-faced, white, crossbred ewes with heavy fleeces of good quality and the capacity for a high level of lamb production when bred to rams of the Cheviot or Down breeds.

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HERITABILITIES OF WEANING WEIGHT, YEARLING WEIGHT, AND CLEAN FLEECE WEIGHT IN RANGE ROMNELET SHEEP[1]

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ABSTRACT

Heritabilities of weaning weight, yearling weight and clean fleece weight for range Romnelet sheep were estimated by the intra-sire regression of daughter on dam from data adjusted for year effects, age of dam, type of birth and rearing and age of lamb or yearling ewe. The data from which each estimate was calculated were collected over a 12-year period.

The estimate for weaning weight based on 694 daughter-dam pairs (26 sire groups) was $0.28 \pm .09$. For yearling weight an estimate of $0.37 \pm .11$ was obtained from 394 daughter-dam pairs (34 sire groups). Five hundred and thirty-seven daughter-dam pairs (27 sire groups) provided an estimate of $0.48 \pm .08$ for clean fleece weight.

INTRODUCTION

Romnelets are a relatively new breed of sheep developed at Manyberries, Alberta, by the Experimental Farms Service, Canada Department of Agriculture, beginning in 1935. The foundation consisted of 15 pure-bred Romney Marsh rams and 520 grade Rambouillet ewes. First-cross lambs were born in 1936, 1937, and 1938. A Targhee ram imported from the U.S. Western Sheep Breeding Laboratory, Dubois, Idaho, was used in the flock in 1942 and 6 Romeldale rams were used in 1944. Two of the Romeldale rams were used again in 1945. With these exceptions, the flock was closed from the time of inter-mating of the first-cross generation. The genealogy of this breed was presented by Peters (19).

The heritabilities of weaning weight, yearling weight, and clean fleece weight in the Manyberries Romnelet flock were calculated in order to assess the possibilities for improvement in these traits.

MATERIALS AND METHODS

Weaning weights were obtained from records of 1532 Romnelet ewe lambs weaned in the 12-year period 1947-1958. During this period part of the Romnelet flock was used in a breed comparison experiment in which male lambs were castrated early after birth. To simplify the analysis all data of the ram lambs were excluded from this study. Records of yearling body weights from 894 Romnelet yearling ewes over a 12-year period, 1949-1960, were used. Yearling weights of ewes were not available prior to 1949. Clean fleece weights were obtained from records of 1055 yearling ewes for the 12-year period 1947-1958. No cross-bred ewes (F_1 generation) were included in these populations. Data of twins were kept as single observations in instances where a dam had more than one offspring in a year.

Most of the lambs each year were born in April or May and were herded with their dams on a short-grass range until weaning time in the

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early part of September. Immediately after that, they were required to graze on the short-grass range without any supplemental feed until snowbound in December or January, depending on weather conditions. Alfalfa hay was fed during the intervening winter months. The body weights were recorded each year approximately at the age of 1 year between April 1 and May 30. All yearling ewes were sheared each year at the end of May. One composite sample of raw fleece was taken from each individual wool clip. The sample was scoured and from this the clean fleece yield was calculated. All data on clean fleece weight include 16 per cent moisture regain.

The effects of four environmental factors on these production traits were calculated by the method of least squares presented by Hazel (5) and applied in a study by Burgess, Landblom, and Stonaker (4). The absorption-iterative method employed by Henderson (11) was used to estimate the various parameters. The details and mechanics of setting up the equations, solving them, and developing the variance study were obtained from Landblom (14). The factors were: year in which the lambs were born; age of dam; type of birth and rearing; and age of ewe lamb or yearling ewe.

The original data for each trait were adjusted for the effects of environmental factors and the subsequent analyses of these data yielded the

TABLE 1. — LEAST SQUARES ESTIMATES OF DEVIATIONS FROM THE MEAN SHOW THE VALUES BY SUB-CLASSES FOR EACH FACTOR

Factor	Sub-class	Estimated of deviation, lb.		
		Weaning weight	Yearling weight	Clean fleece weight
Years	1947	6.07		0.99
	1948	6.59		0.06
	1949	9.15	0.89	0.03
	1950	7.11	−3.92	0.03
	1951	3.81	5.95	0.58
	1952	−9.78	0.32	−0.04
	1953	−12.03	−10.76	−0.66
	1954	−4.41	6.42	−0.29
	1955	−16.32	8.68	0.35
	1956	−8.77	−0.24	−0.58
	1957	6.70	0.79	−0.66
	1958	11.88	7.56	0.18
	1959		−8.67	
	1960		−7.03	
Age of dam	2-year	−1.45	−2.28	−0.01
	3-4-5-year	1.24	1.33	0.08
	6-year and older	0.21	0.94	−0.07
Type of birth and rearing	Singles	5.11	3.63	0.19
	Twins	−7.45	−4.71	−0.23
	Twins raised singly	2.34	1.08	0.04
Regression of performance on age, lb./day		0.36	0.15	0.02
Over-all mean, lb.		64.18	93.80	5.04

heritability estimates. The heritabilities of weaning weight, yearling weight, and clean fleece weight were obtained by doubling the intra-sire regression of daughter on dam, derived from 694, 394 and 537 daughter-dam pairs, respectively.

RESULTS AND DISCUSSION

Environmental Factors

Table 1 shows the estimated deviations of the traits from their means due to the environmental factors. All of these sources of variation had significant ($P < 0.01$) effects (Table 2). These factors represented 44 per cent of the variance in weaning weight, in contrast to 50 per cent found by Hazel and Terrill (6) in Rambouillet lambs, and 56 per cent by Sidwell and Grandstaff (23) in Navajo lambs. Single lambs were 12.5 pounds heavier than twins and lambs raised by mature dams were 2.7 pounds heavier than those raised by 2-year-old ewes. Regression of weaning weight on age was 0.36 pound per day. Differences between years of the 12-year period were high (Table 1). These environmental effects are similar to those found by Sidwell and Grandstaff (23) but they differ from the findings by Hazel and Terrill (6). In the latter study, Rambouillet singles were 9.2 pounds heavier than twins and lambs raised by mature dams were 6.1 pounds heavier than those raised by 2-year-old dams. The regression of weaning weight on age was 0.41 pound per day. In another report Hazel and Terrill (8) reported on the effects of environmental factors on weaning weight in pooled data for Columbia, Corriedale and Targhee lambs. Their results showed that singles were 11.7 pounds heavier than twins, lambs raised by mature dams were 8.7 pounds heavier than those raised by 2-year-old dams, and the regression on age was 0.45 pound per day.

The effects of the four environmental factors on yearling weight represented 47 per cent of the total variance. Yearling ewes from mature dams were 3.6 pounds heavier than those from 2-year-old dams, while yearlings raised as singles were 7.3 and 2.5 pounds heavier than twins and twins raised singly, respectively. The regression of yearling body weight on age was 0.15. The differences were in the same direction as at weaning but some were considerably smaller. Twin lambs tended to overcome, to a certain

TABLE 2. — SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF THREE TRAITS (MEAN SQUARES ONLY)

Source of variance	Weaning weight		Yearling weight		Clean fleece weight	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Total	1531	121	893	169	1054	0.84
Years	11	4665**	11	3234**	11	18.42**
Age of dam	2	813**	2	889**	2	3.29**
Type of birth	2	9836**	2	5702**	2	16.98**
Regression on age	1	8702**	1	796**	1	12.79**
Error	1515	68	877	91	1038	0.32

**Significant at $P < 0.01$

degree, the original handicap in growth rate by the time they were 12 months old. The reduction in regression of body weight on age, from 0.36 pound to 0.15 pound per day, has been observed by other workers (20). The values of the environmental effects reported here are almost identical to those of Price *et al.* (21). Hazel and Terrill (10) found a low regression of body weight on age, 0.031 pound, as compared with 0.15 pound in this work and 0.12 pound in the findings of Price *et al.* (21).

Yearling ewes born as singles gave, on the average, 0.42 pound more clean wool than ewes born and raised as twins, and 0.15 pound more than those born as twins and raised singly. Ewes raised from 3-, 4- and 5-year-old dams had about 0.10 pound more clean wool than those raised by aged ewes. Age at shearing affected the clean fleece weight, since the regression of clean wool on age was 0.02 pound. Hazel and Terrill (10) published results which are similar to those presented here. Range Rambouillet yearling ewes from mature dams produced 0.17 pound more clean wool than those that had 2-year-old dams, while singles produced 0.23 and 0.17 pound more than twins and twins raised singly, respectively. The regression of clean fleece weight on age at shearing was 0.01 pound. Price *et al.* (21) reported environmental effects on clean fleece weight in Navajo yearling ewes. Yearlings from 2-year-old and mature dams differed, on the average, by 0.04 pound of clean fleece weight; singles and twins, by 0.35 pound; singles and twins raised singly, by 0.16 pound; and the regression of clean fleece weight on age was 0.02 pound.

Heritability

The statistics from which the estimates of heritability were computed and the resulting estimates are shown in Table 3. Included also are the numbers of dams, sires, and daughter-dam pairs. A dam's record was repeated for each offspring. The heritability estimates were based on the adjusted data.

The intra-sire regression coefficient of daughter on dam for weaning weight, 0.142 ± 0.045, was significant ($P < 0.01$). The estimated heritability of 0.28 is similar to the estimates found by other workers. Hazel and Terrill (7, 9) reported the heritability of weaning weight in Rambouillet lambs to be 0.30, and in Columbia and Corriedale lambs, 0.18 and

TABLE 3.—NUMBERS OF SIRES, DAMS, AND DAUGHTER-DAM PAIRS, MEAN SQUARE, COVARIANCE, AND HERITABILITY ESTIMATE FOR EACH TRAIT

Trait	Numbers			Mean square (dams)	Covariance (offspring-dam)	Heritability
	Sires	Dams	Pairs			
Weaning weight	26	367	694	49.373	7.038	0.284±0.090
Yearling weight	34	258	394	72.215	13.271	0.368±0.106
Clean fleece weight	27	334	537	0.574	0.139	0.484±0.082

0.38, respectively. MacNaughton (15) found the heritability to be 0.33 and 0.45 in Rambouillet and Canadian Corriedale lambs, respectively.

The estimate obtained for the heritability of yearling weight was 0.37. The intra-sire regression coefficient of daughter on dam, 0.184 ± 0.053, was significant ($P < 0.01$). This heritability is similar to the estimate of Terrill and Hazel (24), 0.40, for range Rambouillet ewes.

Yearling body weight is a very important production trait. Joseph (13) reported that size of ewe was the most accurate single measure of ewe's ability to produce heavy lamb crops. In addition, heavier fleeces were produced by larger ewes. Hunt (12), working with both mutton and fine-wool sheep, also found that lamb and wool production increased with the size of the ewe. Bonsma (2) reported that, within breeds, milk production of ewes increased with body weight.

There was a significant ($P < 0.01$) intra-sire regression of offspring on dam for clean fleece weight, 0.242 ± 0.041. The heritability of 0.48 is in general agreement with results of other workers. Briggs (3) found a daughter-dam correlation of 0.57 for clean wool production in Rambouillet sheep. Terrill and Hazel (24) reported a heritabiltiy of 0.38 in Rambouillet yearling ewes. Shelton *et al.* (22) found the heritability of this trait to be 0.61. Morley (16, 17) reported heritability estimates of 0.62 and 0.47 for clean fleece weight in Australian Merinos.

Grease fleece weight has been used as the selection criterion in most wool-improvement programs. Clean fleece weight, however, is a more accurate datum for selection as it does not include the variation in individual wool clips due to moisture, dirt, grease, etc. The determination of clean fleece weight was slow and costly and, therefore, impractical for recording. Since a squeeze-machine was invented by Neale (1, 18), the application of clean fleece weight for selection has become practical.

From the heritability estimates obtained here it can be concluded that genetic improvement in clean fleece weight can be made through selection. Improvement in weaning weight and yearling weight will be somewhat slower.

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AN APPRAISAL OF RUELENE AND TROLENE AGAINST CATTLE GRUB INFESTATIONS, (OESTRIDAE: DIPTERA)[1]

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ABSTRACT

The reductions in numbers of cattle warble grubs produced by Ruelene and Trolene in a heavily infested cattle herd were compared. Ruelene intramuscular injections at 5 mg./kg. and 10 mg./kg. and Trolene boluses at 105 mg./kg. reduced the numbers of grubs by 83, 86 and 86 per cent, respectively. Statistically these reductions were not significantly different. The intramuscular injections did not cause detectable lesions at the injection site in the 90 calves treated. The injection method was preferred to the bolus method for ease of administration, economy of labour, and decreased danger of injury to animals. Feeding Ruelene at 5 mg./kg. and 10 mg./kg. daily for 5 days, and feeding Trolene at 15 mg./kg. daily for 7 and 12 days, reduced the numbers of grubs by 95, 94, 94 and 97 per cent respectively. These reductions were not significantly different.

INTRODUCTION

In 1956 two compounds, *O. O*-dimethyl O-(2, 4, 5-trichlorophenyl) phosphorothioate (Dow ET57)[3] administered as a bolus or pill, and *O, O*-diethyl *O*-(3-chloro-4-methyl-7-coumarinyl) phosphorothioate (Bayer 21/199)[4] applied as a spray, were introduced for field testing as systemic insecticides for control of cattle warbles, *Hypoderma bovis* (L.) and *H. lineatum* (DeVill.). In 1957 and 1958 both compounds were registered for distribution in Canada and the United States under the trade name of Trolene and Co-Ral, respectively, and an extensive literature on their use has been subsequently amassed. In 1957 Trolene was again introduced for testing as a feed additive, [French and Raun (3), Rich and Ireland (6)]. Also several new compounds, including *O*-4-*tert*-butyl-2-chlorophenyl-*O*-methyl methylphosphoramidothioate (Dowco 109)[3], were introduced (6).

In 1958 it was found that the oxygen analogue or first metabolic breakdown product of Dowco 109, *O*-4-*tert*-butyl-2-chlorophenyl *O*-methyl methylphosphoramidate (Ruelene)[3], was only moderately more toxic than the parent compound and appeared to have not only increased systemic insecticidal activity but also a high level of anthelmintic activity (2). This new compound was introduced for testing in 1959 in formulations suitable for spray, feed-additive and parenteral applications.

Rich and Ireland (6), and Rich (7) have previously discussed the difficulties associated with prehypodermal spray application in central British Columbia. Therefore Ruelene spray was not tested in 1959. Intramuscular injection and feed-additive tests were carried out and are discussed in this report.

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MATERIALS AND METHODS

Test Animals

The animals used were grade Hereford calves born prior to June 1, 1959, from the herds of the Harper Ranch, Kamloops, British Columbia, and the Quilchena Cattle Company, Nicola, British Columbia. On each ranch the calves had ranged together as a group from birth and thus had been uniformly exposed to warble infestation. Medium-sized calves were selected to give a high degree of uniformity of weight and vigour. On each ranch treatment was made as soon as possible after the calves had been weaned.

Each test group comprised 30 calves. These were selected, weighed, marked with numbered ear-tags, and treated in accordance with previously prepared randomization schedules. Subsequent sales of some calves to calf-clubs reduced the numbers of calves in several groups to less than 30.

Insecticide Formulations

The Trolene boluses and feed-additive formulations used contained 40 per cent by weight active insecticide. The Ruelene additive formulation contained 25 per cent active insecticide. The Ruelene solution for intramuscular injection, company formulation M-1409, contained 500 milligrams of insecticide per c.c. of solution.

Insecticide Treatment

Trolene in boluses and in feed had been tested against cattle grubs at the Harper Ranch in each of the 3 and 2 previous years, respectively (8, 6, 7). Therefore, treatments with these materials were again applied in order to compare Ruelene with an insecticide of known effectiveness. The Ruelene injection test at the Quilchena Cattle Company was a duplication of the similar test at the Harper Ranch and was applied on January 6, 1960. At the Harper Ranch, bolus and injection treatments were applied on December 10, 1959, and feed-additive treatment commenced on December 17, 1959.

Each calf was weighed to an accuracy of $\pm$ 2.5 pounds. Bolus dosages were adjusted to an accuracy of $\pm$ 0.25 bolus and injection dosages to an accuracy of $\pm$ 0.25 c.c., according to individual animal weight. The feed-additive formulations were carefully blended by the feed formulator into an unpelleted feed supplement containing molasses at the desired level of insecticide intake based on the weight of the test group, at an allowance of 2 pounds of feed supplement per calf per day.

During selection the feed-additive test groups were isolated into separate feed-lots. They were then conditioned to acceptance of untreated supplement for 7 days, and then offered the treated supplement daily for the required number of days (Table 1). During conditioning and treatment the supplement was offered to the calves in troughs each morning and no other feed was supplied until the supplement had been eaten.

Collection of Warble Grubs

Grubs were collected by removal of all detectable hypodermal stage grubs. At the Harper Ranch, six collections were made at 14-day intervals

TABLE 1.—SUMMARY OF DATA ON WARBLE GRUB INFESTATIONS IN CALVES TREATED WITH TROLENE AND RUELENE AT VARIOUS DOSAGES AND IN VARIOUS FORMULATIONS

	Harper Ranch, Kamloops								Quilchena Cattle Company, Nicola	
Insecticide	None	Trolene	Ruelene	Ruelene	Trolene	Trolene	Ruelene	Ruelene	None	Ruelene
Total dosage mg./kg.	0	105	5	10	105	180	25	50	0	10
Daily dose mg./kg.	0	105	5	10	15	15	5	10	0	10
Duration of treatment, days	0	1	1	1	7	12	5	5	0	1
Method of administration	0	Bolus	Intra-muscular	Intra-muscular	Supple-ment	Supple-ment	Supple-ment	Supple-ment	0	Intra-muscular
Number of calves	28	28	26	27	28	29	30	30	35	35
Number of calves infested	23	16	10	9	12	5	10	11	15	1
Mean number of grubs per calf	32.2	3.3	7.3	3.0	1.7	1.2	1.2	1.9	4.6	0.3
Range of grubs per calf	0-141	0-17	0-72	0-27	0-30	0-25	0-15	0-34	0-35	0-11
Mean number of grubs transformed[1]	1.052	0.379	0.449	0.258	0.195	0.117	0.174	0.212	0.416	0.031
S.E. of difference from untreated	—	0.168	0.179	0.177	0.161	0.159	0.163	0.171	—	0.103
Mean percentage reduction, transformed	—	86	83	86	94	97	95	94		96

[1]By the formula log x +1

from January 21, 1960 to March 31, 1960, inclusive. On both March 17 and 31 the number of grubs collected from the untreated group averaged less than 0.5 grubs per animal. At the Quilchena Cattle Company, a single collection was made at the estimated time of maximum grub density on February 28, 1960.

Analysis of Data

The data were transformed logarithmically before analysis, because of the skewness of the distributions of the grub counts.

RESULTS AND DISCUSSION

No boluses were regurgitated. All the feed-additive test calves appeared to accept the feed supplement readily during both the conditioning and the treatment period. No toxicity symptoms were observed in any of the calves. No irritation was seen at the sites of intramuscular injection and neither abscesses nor lumps were detectable by palpation throughout the grub collection period.

During all treatments the temperatures ranged from 25 to 32°F. During the Harper Ranch treatment the injectable solution was kept warm. However, in a replicate test attempted on December 17, 1960, the solution became cold and crystallization with precipitation occurred and the test was abandoned. The insecticide was restored to solution by immersion for 1 hour in a water-bath at 75°F. before the Quilchena Cattle Company test was carried out.

Summarized data (Table 1) for each test group show that, at the dosage levels tested, the reductions in numbers of grubs produced by Ruelene were comparable with those produced by Trolene for both the single dose and the multiple dose methods of treatment.

The reductions produced by Trolene boluses and by Ruelene intramuscular injections at 10 mg./kg. were identical. The difference in reductions for the 5 mg./kg. and 10 mg./kg. Ruelene injections were not statistically significant at the 5 per cent level. This difference resulted from the occurrence of 72 grubs in 1 calf of the 5 mg./kg. test group. This was 38 per cent of the total of 190 grubs recovered from the 26 calves in the group. Injection was into the right shoulder muscles and was carefully administered; however, it is possible that this calf actually received a low dosage because of leakage of solution during withdrawal of the injection needle.

Cattle, especially range-bred animals, almost invariably resist bolus treatment and must be individually restrained. During the application of close restraint there is always a possibility of injury occurring. For example, in 1957 during treatment of a large range herd with boluses, one cow strongly resisted restraint and, in so doing, broke her right hind pastern joint and was accordingly slaughtered. Also, there is a possibility that boluses may cause injury to the throat during administration (6), particularly if an animal resists treatment. Thus bolus treatment is relatively slow and laborious and is hazardous to the animals. Conversely injections can be rapidly administered and require only a minor degree of restraint.

For injections, range animals are commonly treated in an ordinary corral chute. Therefore, when insecticidal effectiveness and animal toxicity are comparable, as they appear to be with these two materials, the injection method is preferable to the bolus method.

There was also no significant difference between the reductions in numbers of grubs produced by either material in the feed-additive formulations. Neither was there any significant difference in the reductions produced by the two dosage levels used for each material. The low reduction observed for the higher Ruelene dosage resulted from a high infestation in 1 of the 30 calves in the group. Thirty-four, or 59 per cent of the total of fifty-eight grubs collected from the group, were collected from this animal. This type of variation has been observed in previous feed-additive tests using Trolene and Dowco 109, and has been attributed to inequality of dosage resulting from variation in animal feed intake rates (6, 7). Mayhew (4), Baker and Allen (1), and others have reported that inequality of dosage occurs in cattle fed in phenothiazine as an anthelmintic and, more recently, Radeleff (5) has discussed this in relation to the feeding of systemic insecticides. The addition of insecticide to feed permits a non-residual systemic insecticide to be maintained at an effective level in the blood for a much longer period than is possible with a single treatment, but this factor of unequal dosage seriously detracts from the value of the method.

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THE EFFECT OF A PURIFIED SOURCE OF CELLULOSE ON THE GROWTH AND BODY COMPOSITION OF GROWING PIGS[1]

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ABSTRACT

One hundred pigs were used in two experiments to determine the nutritive value of a purified source of cellulose (solka-floc) and its effect on body composition and iodine number of the loin fat. In each experiment one group of pigs received a basal ration *ad libitum* while levels of 10 and 40 per cent solka floc were added to the basal ration of two groups at 62 and 162 pounds liveweight, respectively. The pigs given solka-floc were fed *ad libitum* and the amounts of basal ration consumed were pair-fed to two respective control groups. There was a significant decrease ($P < .01$) in dressing percentage of pigs fed solka-floc. Feed efficiency, based on total feed (less solka-floc) per pound of gain, was better in the pair-fed controls reaching statistical significance ($P < .05$) in one experiment. There was no significant difference in the protein or fat content of the carcasses but the iodine number of the loin fat was significantly higher ($P < .01$) in pigs fed solka-floc. It was concluded that in growing pigs there is no net gain in energy from the consumption of cellulose.

INTRODUCTION

High fibre rations are commonly used to provide a method of feed restriction when self-feeding market pigs. There is, however, very little information to show if the additional cellulose in a fibrous ration is of any net value to the pig in regard to feed efficiency or carcass composition. Several workers (3, 4, 6) have recorded lower dressing percentages in pigs fed high fibre rations. Bohman *et al.* (4) observed that rations containing 50 per cent alfalfa increased the weight of the stomach and large intestines of growing pigs while Hochstetler *et al.* (9) reported that rations containing 40 per cent of oats, bran or alfalfa had no significant effect on the weights of the stomach or intestinal tissues. Whiting and Bezeau (12, 13) reported that an increase in the fibre level of a ration increases the metabolic fecal nitrogen excretion of pigs and that the level of excretion depends upon the type of fibre fed. Clausen and Ludvigsen (5) recently reported that, in addition to reducing the thickness of the back fat of pigs, fillers such as fibrous feeds may also produce a softer fat.

Two experiments were conducted to determine the nutritive value of a purified source of cellulose (solka-floc[4]) and its effects on body composition and on the iodine number of back fat.

EXPERIMENTAL PROCEDURE

Experiment 1

Fifty Yorkshire pigs, twenty-five males and twenty-five females from the same boar and from half-sib dams, were allotted according to age and sex into five groups when they reached 62 pounds on weight. The groups were treated as follows:

Group 1. *Controls.* Self-fed ration A (Table 1) to 110 pounds liveweight and ration B from 110 to 192 pounds.

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[4]Pure wood cellulose, obtained from Brown Corp., Montreal, Que.

Group 2. *Early restricted with low fibre.* Self-fed ration A_1 to 110 pounds and ration B_1 from 110 to 192 pounds.

Group 3. *"Basal" feed controls for Group 2.* Fed 10 pounds of rations A and B for every 11 pounds of rations A_1 and B_1 respectively, consumed on the average by Group 2.

Group 4. *Late restricted with high fibre.* Self-fed the same rations as Group 1 up to 162 pounds and then self-fed ration C_1 to 192 pounds.

Group 5. *"Basal" feed controls for Group 4.* Self-fed the same rations as Group 1 up to 162 pounds and then fed 10 pounds of ration C for every 14 pounds of ration C_1 consumed on the average by Group 4 to 192 pounds.

All rations were pelleted. Each pig was fed individually and weighed weekly. The pigs were changed from growing rations to finishing rations and marketed when they were within 5 pounds of the weights given in the above schedule. On reaching market weight, the feed was removed for 20 hours, the pigs were weighed again, shipped and slaughtered 4 hours later. Carcass measurements (1) included dressing percentage, carcass weight and length, fat depths at shoulder and loin, and area of loin muscle. The stomach and the large intestines were tied off at slaughter to prevent loss of their contents. Weights of the total viscera (stomach, spleen and intestines with contents) were obtained on all pigs but the full and empty weights of the stomach, small and large intestines stripped of mesentery were recorded for Groups 1, 2 and 4.

Experiment 2

This experiment was similar to Experiment 1, except that individual paired feeding techniques were employed. Five males or five females were selected from each litter and allotted at random to each of the five treatments in Experiment 1. Twenty-five males and twenty-five females were allotted in this way so that each of the pigs in Groups 3 and 5 could be individually pair-fed daily according to the feed consumed by their littermates in Groups 2 and 4 respectively. The pigs were fed on the same schedule as in Experiment 1 and were marketed at the same weights. Carcass appraisal was the same as in Experiment 1 but, in addition, one-half of

TABLE 1. — PHYSICAL COMPOSITION AND PROXIMATE ANALYSIS OF THE EXPERIMENTAL RATIONS

Ration	A	A_1	B	B_1	C	C_1
Barley	87.22	87.22	94.27	94.27	78.27	78.27
Soybean oil meal	6.00	6.00	2.00	2.00	10.00	10.00
Meat scraps (50%)	2.00	2.00	1.00	1.00	5.00	5.00
Fish meal (65%)	3.00	3.00	1.00	1.00	5.00	5.00
Iodized salt	.50	.50	.50	.50	.50	.50
Aurofac-10	.05	.05	—	—	—	—
Ground limestone	1.00	1.00	1.00	1.00	1.00	1.00
Fish oil (300 D, 1500 A)	.20	.20	.20	.20	.20	.20
Zinc sulphate	.03	.03	.03	.03	.03	.03
Solka floc	—	10.00	—	10.00	—	40.00
Crude protein (%)	18.9	17.1	14.5	12.9	19.7	14.3
Crude fibre (%)	5.0	10.5	5.0	9.8	6.8	23.2
Ether extract (%)	1.4	1.0	2.0	1.6	2.7	1.9
Ash (%)	6.1	5.4	5.0	4.2	6.8	5.4
N.F.E. (%)	68.6	66.0	73.5	71.5	63.9	55.2

each carcass (packer-style) was returned to the laboratory. Cores of the back fat were taken in the loin area and iodine numbers were obtained by the Hanus method (2). The half carcasses of ten males and ten females from four sets of litter mates were selected at random from the ten sets of litter mates for carcass analysis. They were individually minced while still frozen with a mincer described previously (7) and thoroughly mixed in a Hobart mixer. The minced tissue was sampled and analysed for moisture, ash and protein by routine methods (2). Lipids were determined by a modification of the Saxon procedure (8).

RESULTS AND DISCUSSION

The results of Experiments 1 and 2 are shown in Tables 2 and 3, respectively.

Weight Gains and Feed Efficiency

The pigs in Group 1, fed the control ration *ad libitum*, reached market weight earlier than the other groups in both experiments but an analysis of variance indicated that the differences in days on experiment and average daily gain did not reach statistical significance. The rate of gain in the first experiment was not as rapid as in the second. Some of the pigs in

TABLE 2. — AVERAGE FEED EFFICIENCY, CARCASS MEASUREMENTS AND VISCERA WEIGHTS OF PIGS IN EXPERIMENT 1[1]

	Groups				
	1	2	3	4	5
Ration	A,B	A_1B_1	A,B	A,B,C_1	A,B,C
Initial weight (lb.)	62.1	62.8	63.8	63.0	63.5
Days on experiment	102.9	127.4	107.1	112.7	105.7
Wt. loss in 20 hr. before shipping (lb.)	4.7	5.4*	3.3	6.3*	3.6
Dressing % of final wt.	79.6	78.8	79.2	77.1*	79.2
Dressing % of shipping wt.	81.6	81.1	80.6	77.8	80.7
Daily gain (lb.)	1.27 (6.21)[2]	1.10	1.19	1.18	1.21
Total feed per day	5.09	4.58	4.21	(5.44)	(3.73)
"Basal" feed per 100 lb. gain[3] (lb.)	401	420*	357	384	397
"Basal" feed per 100 lb. carcass gain[4] (lb.)	490	511**	439	490	488
Shoulder fat (in.)	1.90**	1.76	1.61	1.71	1.70
Loin fat (in.)	1.31	1.26	1.16	1.34	1.20
Area of loin (sq. in.)	4.02	3.97	4.15	4.03	4.15
Length of side (in.)	30.8	31.0	31.0	30.8	30.7
Total wt. of viscera (lb.)	15.8	15.7	17.6	16.7	17.1
Stomach, full (lb.)	1.95	2.20		2.11	
empty (lb.)	1.03	1.06		.97	
Small intestine, full (lb.)	3.37	2.84		2.71	
empty (lb.)	2.11	1.78		1.94	
Large intestine and cecum, full (lb.)	5.34	5.48		6.56	
empty (lb.)	1.54	1.56		1.58	

[1]Asterisks beside Groups 2 and 4 indicate significance between Groups 2 and 3 or between Groups 4 and 5, while asterisks beside Group 1 indicate significance between Group 1 and Groups 2, 3, 4 and 5.
[2]Figures in brackets are for the period from 162 to 192 lb. in body weight. The other figures are for the entire experimental period.
[3]"Basal" feed equals total feed intake less solka-floc.
[4]Carcass gain was calculated using an estimated dressing percentage of 75 per cent for all pigs at the beginning of the experiment.
*Significant at the 5% level of probability
**Significant at the 1% level of probability

each group in Experiment 1 did not eat well and grew slowly, but examination of the affected animals by pathologists before and after slaughter failed to reveal any abnormality.

The inclusion of solka-floc in the rations did not result in a general increase in total daily feed consumption to compensate for the lower digestible nutrient content of ration. Only in the case of the pigs in Group 4, Experiment 2, did the total daily feed consumption exceed that of the Group 1 controls but the differences were not statistically significant. Chicks in a concurrent study in this laboratory (10) consumed more total feed as the level of solka-floc in the ration was increased but they did not compensate sufficiently to bring their "basal" feed consumption (total feed less solka-floc) up to that of the controls. The use of "basal" feed provided a better assessment of the effect of fibre when comparing solka-floc-fed pigs and their respective pair-fed controls. The work of Teague and Hanson (11) shows that the compensatory reaction of pigs to fillers may be quite variable and may differ greatly from one experiment to the next.

Feed efficiency in Tables 2 and 3 is expressed on the basis of "basal" feed per 100 pounds of gain and "basal" feed per 100 pounds of carcass gain. The use of "basal" feed per 100 pounds of carcass gain takes into considera-

TABLE 3. — AVERAGE FEED EFFICIENCY, CARCASS MEASUREMENTS AND VISCERA WEIGHTS OF PIGS IN EXPERIMENT 2[1]

	Groups				
	1	2	3	4	5
Ration	A,B	A_1,B_1	A,B	A,B,C_1	A,B,C
Initial weight (lb.)	59.2	59.9	60.9	60.1	60.5
Days on experiment	79.1	84.0	83.3	81.9	81.2
Wt. loss in 20 hr. before shipping (lb.)	5.8	7.6	6.6	9.3*	6.3
Dressing % of final wt.	77.8	76.2	76.9	75.0**	77.8
Dressing % of shipping wt.	80.2	79.3	79.7	78.7	80.4
Daily gain (lb.)	1.68 (7.00)[2]	1.59	1.58	1.68	1.61
Total feed per day	6.04	5.84	5.30	(7.35)	(5.19)
"Basal" feed per 100 lb. gain[3] (lb.)	359	334	336	338	338
"Basal" feed per 100 lb. carcass gain[4] (lb.)	441	435	430	450	427
Shoulder fat (in.)	1.85	1.84	1.84	1.71	1.83
Loin fat (in.)	1.36	1.35	1.32	1.28	1.38
Area of loin (sq. in.)	3.78*	3.95	3.83	3.87	3.94
Length of side (in.)	30.5	30.8	30.5	30.8	30.5
Carcass: Protein %	13.8	14.1	13.7	13.9	14.5
Fat %	42.9	43.6	43.4	42.2	41.6
Ash %	2.6	2.6	2.7	2.6	2.7
Iodine No, loin fat	58.6	60.4**	58.3	60.7	59.9

[1]Asterisks beside Groups 2 and 4 indicate significance between Groups 2 and 3 or Groups 4 and 5, while an asterisk beside Group 1 indicates significance between Group 1 and Groups 2, 3, 4, and 5.
[2]Figures in brackets are for the period from 162 to 192 lb. in body weight. The other figures are for the entire experimental period.
[3]"Basal" feed equals total feed intake less solka-floc.
[4]Carcass gain was calculated using an estimated dressing percentage of 75 per cent for all pigs at the beginning of the experiment.
*Significant at the 5% level of probability
**Significant at the 1% level of probability

tion the effect of fill and dressing percentage. There was no significant difference in the "basal" feed per 100 pounds gain between groups fed solka-floc and their respective pair-fed groups, except that, in Experiment 1, Group 3 was significantly more efficient than Group 2 ($P < .05$). When feed efficiency was expressed as feed per 100 pounds of carcass gain the groups that received solka-floc tended to become comparatively less efficient. This would indicate that, in the growing pig up to 192 pounds, cellulose has no net nutritional value and may even exert a negative effect. Chicks that received solka-floc in similar studies at this station required significantly more "basal" feed per pound gain than pair-fed controls (10).

Dressing Percentage and Viscera Weights

Greatest weight losses in the 20 hours prior to shipping were found in the groups fed solka-floc. These differences were significant ($P < .05$) between Groups 2 and 3 in Experiment 1 and between Groups 4 and 5 in Experiments 1 and 2. This was reflected in a lower dressing percentage based on the final weight. There was also a slight but not significantly lower dressing percentage, based on the shipping weight, in the solka-floc pigs. This was expected to have been caused by heavier viscera (4) but the weights of the viscera with contents of the solka-floc fed pigs were no greater than those of pair-fed controls. The contents of the large intestines and cecums of Group 4 were more than 1 pound greater than those of Groups 1 and 2 but the differences were not statistically significant. There were also no differences in the weights of the empty stomachs and intestines, indicating that the amount and type of fibre used in this experiment had no apparent effect on the gastro-intestinal tissues.

Carcass Measurements and Carcass Composition

There was a trend for the control pigs in Group 1 to have a greater depth of back fat and a smaller area of loin but only a few differences in carcass measurements were statistically significant. An analysis of variance indicated that Group 1 had a significantly greater depth of shoulder fat than the other groups ($P < .01$) in Experiment 1 and a smaller area of loin ($P < .05$) in Experiment 2.

The carcass analysis of four pigs from each group in Experiment 2 did not show any large differences between groups. Higher carcass protein was found in Groups 2 and 5 in which larger areas of loin had been recorded but the differences were not statistically significant. There were highly significant ($P < .01$) differences between males and females in protein, fat and ash and in all carcass measurements in both experiments.

The degree of feed restriction obtained in these experiments was, therefore, not sufficient to improve all carcass measurements and would indicate that greater dilution of the ration would be required to prolong the growing period sufficiently to produce carcasses of more desirable quality.

Iodine Number

An analysis of variance indicated a highly significant difference between groups in the iodine numbers of the loin fats (Table 3). Groups 2 and 4

which received solka-floc had higher iodine numbers than their respective pair-fed groups but only the differences between Groups 2 and 3 were statistically significant ($P < .01$). Clausen and Ludvigsen (5) reported a softer fat in pigs fed high fibre rations but, even though such differences may exist, they were sufficiently small under the conditions of this experiment to be of little practical consideration.

In conclusion, the data obtained in these experiments show that the growing pig derives no net gain in energy from dietary cellulose. Rations diluted with cellulose result in a variable degree of feed restriction, a lower dressing percentage, and produce a slightly softer fat.

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GENETIC TRENDS IN PERFORMANCE OF THE ROMNELET SHEEP DURING THE PERIOD OF BREED DEVELOPMENT[1]

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ABSTRACT

Performance records on the Romnelet sheep, developed from the Romney X Rambouillet cross [with introductions of Targhee and Romeldale in the early years], were analysed to determine genetic trends in birth weight, weaning weight, 18-month weight of ewes and yearling clean fleece weight from the F1 to the F7 generation.

There were statistically significant ($P < 0.01$) reductions of 1.3 pounds in birth weight, 7.5 pounds in weaning weight at an average age of 136 days, 7.0 pounds in 18-month weight of ewes and 0.6 pound in yearling clean fleece weight from the first-cross to the F2 generation. There was a further significant ($P < 0.05$) decline of 0.6 pound in birth weight and a significant ($P < 0.01$) decline of 0.5 pound in clean fleece weight after the F2 generation, but no further significant change occurred in 18-month weight of ewes. There was a significant ($P < 0.05$) increase of 7.8 pounds in weaning weight in the later generations.

INTRODUCTION

Most of the analyses of selection and its effects in farm animals have involved estimation of time trends in performance. Various workers have pointed out the sources of error that can make time trends misleading as measures of genetic change (8, 11, 12, 24). Damon and Winters (6) were able to demonstrate a consistent and substantial improvement in management, and a method was devised to measure this managerial trend in order to proportion properly the improvement due to management and that due to genetic gains.

The existence of variation in birth weights of lambs due to sex, age of dam and type of birth (single or twin) has been demonstrated experimentally by Ali (1), Blackwell and Henderson (2), Chapman (5), Kincaid (17), MacNaughton (18), Nelson and Venkatachalam (20) and others. Bogart *et al.* (3) found that type of birth contributed more consistent effects on birth weight than sex, year, breed or top-cross of ewe or breed of sire.

Effects of weaning age, sex, age of dam and type of rearing (single, twin raised singly or twin raised as twin) on weaning weight have been reported extensively (1, 2, 4, 7, 14, 15, 18, 20, 25, 26). Phillips and Dawson (22) found that single lambs were favoured over twins at selection and that older and heavier lambs were favoured over younger and lighter lambs.

Hazel and Terrill (16) reported that yearling Rambouillet ewes from mature dams and those raised as singles were heavier and produced heavier grease fleeces and more clean wool than ewes from 2-year-old dams and those raised as twins, respectively. Similar differences were reported by Terrill, Sidwell and Hazel (28, 29) for Columbia and Targhee sheep.

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[1]Contribution from the Research Branch, Canada Department of Agriculture; adapted from thesis submitted by the senior author to the Graduate Faculty, University of Minnesota, St. Paul, Minn., in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Although there was general agreement among these investigators concerning the nature of intra-year environmental effects, the magnitude of constants computed for the adjustment of data varied between breeds and from one location to another.

Consideration must be given to environmental effects between and within years if accurate estimates of genetic trends in performance are to be obtained.

Performance records on the Romnelet sheep, developed from the Romney X Rambouillet cross at the Canada Experimental Farm, Manyberries, Alberta, provided an opportunity for analyses of genetic trends in economic traits from the first-cross (F1) to the F7 generation. The present paper reports these trends and the methods used in their estimation.

MATERIALS AND METHODS

The history and genealogy of the Romnelet and the methods of breeding used in developing the breed have been reported (21). In brief, the project began in 1935 with the crossing of 15 Romney Marsh rams on 520 Rambouillet ewes. First-cross animals were produced in 1936, 1937 and 1938. Introductions were made of 1 Targhee ram in 1942 and 6 Romeldale rams in 1944 and 2 of the Romeldale rams were used again in 1945. The flock was closed to outside introductions in 1945.

For the present study, all animals born in the years 1936 to 1955, inclusive, were classified according to generation as follows: offspring of Romney/Rambouillet mating = F1, F1/F1 = F2, F2/F3 = F3.5, Targhee/F4 = F3, Romeldale/F4 = F3, etc. In making generation comparisons, F3.75-4.25 animals were classified as F4, F4.75-5.25 as F5, etc. Generation scores of the 1955 lambs ranged from 5.0 to 7.1 and averaged 6.2.

Birth and weaning weights of lambs and weights of ewes at about 18 months of age were available for all generations, although the records were incomplete for some of the early years. Only spring weights from 1950 to 1956 were available for yearling rams.

Grease fleece weights of yearling rams and yearling ewes were kept for all years, but the recording of clean fleece weights did not begin until 1946. For a comparison of F1 with F2, clean fleece weights were estimated from the regressions of clean fleece weight on grease fleece weight computed from data on 444 rams and 987 ewes born from 1945 to 1955.

Analyses of birth weights, weaning weights, 18-month weights of ewes and yearling clean fleece weights were undertaken to determine the genetic trends in these traits from the F1 to the F7 generation.

There were large yearly fluctuations in performance due to feed and climatic factors. Within years, the youngest ewes generally produced the lambs with the highest generation scores. This relationship was checked by intra-year regression of age of dam on generation score of 585 rams born from 1941 to 1955. There was a significant ($P < 0.01$), heterogeneous ($P < 0.01$) regression of −1.3 years in age of dam per unit of increase in generation score of rams. There was also large disproportionality in year-generation sub-classes because of the more or less continuous increase in

mean generation score through the years. In order to avoid errors of inference that might arise as the result of disproportionality of sub-class numbers, generation differences were computed on an intra-class basis by the methods described by Snedecor (27).

Different sub-classes were employed for lambs out of aged, 4-6-year-old, 3-year-old, 2-year-old and yearling ewes, for male, wether and female lambs, and for singles, twins raised singly and twins raised as twins. This classification was used by MacNaughton (18).

Weaning weights were adjusted for age as indicated by intra-class, intra-year regression analysis. Data on yearling performance traits were adjusted for age according to intra-year regression analysis. Tests for significance, heterogeneity and linearity according to Goulden (13) and Snedecor (27) were performed in computing regression coefficients and equations for the adjustment of data.

Data for a comparison of F1 with F2 on an intra-year basis were available only in 1938. In that year, the F1 lambs were out of 2-year-old ewes. In order to obtain valid comparisons of the F1 and F2 generations, age-of-dam effects were computed by intra-class, intra-generation analyses of variance on performance data of Romnelets out of 6-year-old and 2-year-old ewes during the period of breed development.

RESULTS AND DISCUSSION

Intra-Year Environmental Effects

The means of birth weight and weaning weight for age of dam, sex and type of birth or rearing sub-classes are given in Tables 1 and 2, respectively. These results support the conclusion of other workers that intra-year environmental variables have a significant bearing on the performance of range lambs.

TABLE 1. — AVERAGE BIRTH WEIGHT OF LAMBS BY TYPE OF BIRTH, SEX, AND AGE OF DAM, 1937 TO 1955, INCLUSIVE

	Age of dam, years (1937 to 1955, inclusive)					
	Aged	4-6	3	2	1	All[1]
Number of lambs						
Single male	36	557	440	592	17	1,625
Single female	36	552	402	722	13	1,712
Twin male	86	795	319	151	0	1,351
Twin female	82	860	346	141	0	1,429
All	240	2,764	1,507	1,606		
Average birth weight, lb.						
Single male	10.6	10.5	9.9	9.2	8.2	10.0
Single female	9.4	9.7	9.2	8.6	7.9	9.2
Twin male	8.8	8.7	8.3	7.8	—	8.4
Twin female	8.1	8.2	7.8	7.3	—	7.8
All	9.2	9.3	8.8	8.2		

[1]Excluding lambs out of yearling ewes

TABLE 2. — AVERAGE WEANING WEIGHT OF LAMBS BY TYPE OF REARING, SEX, AND AGE OF DAM. 1938 TO 1955, INCLUSIVE

	Age of dam, years					
	Aged	4-6	3	2	1	All[1]
Number of lambs						
Single:						
Male	15	222	161	230	14	628
Wether	14	141	134	155	0	444
Female	33	478	355	609	10	1,475
Twin raised singly:						
Male	10	66	22	23	0	121
Wether	5	38	15	13	0	71
Female	19	134	56	33	0	242
Twin raised as twin:						
Male	30	265	121	35	0	451
Wether	16	119	78	14	0	227
Female	44	526	211	66	0	847
All	186	1,989	1,153	1,178		
Average weaning weight, lb.[2]						
Single:						
Male	71.1	74.9	77.5	70.6	46.9	73.5
Wether	70.1	70.6	68.4	65.6	—	68.7
Female	66.9	69.8	67.4	63.6	45.3	66.9
Twin raised singly:						
Male	66.0	69.8	77.2	67.0	—	70.0
Wether	68.2	66.4	69.7	60.2	—	66.1
Female	62.1	66.8	63.7	63.4	—	64.0
Twin raised as twin:						
Male	52.5	61.5	61.7	58.4	—	58.5
Wether	57.4	57.7	55.6	61.4	—	58.0
Female	57.1	57.2	57.7	57.1	—	57.3
All	63.5	66.1	66.5	63.0	—	

[1]Excluding lambs out of yearling ewes
[2]The average age at weaning was 136 days

The effects of age on performance are summarized in Table 3. Since weaning weights and yearling performance data were taken for all animals on the same dates each year, variations in age were due to date of birth. Wide fluctuations in climatic factors and in the quality and availability of feed during lambing occur within and between years on western ranges, so that an early birth date might be advantageous in one year and have the opposite effect in the following year. Variation in age effects is indicated by the heterogeneity of the regressions of weaning weight of lambs and clean fleece weight of yearling ewes on age.

There were significant ($P < 0.01$) intra-year regressions of 0.50 and 0.54 pound of clean wool per pound of grease wool for rams and ewes, respectively. The correlation coefficient was 0.81 for both sexes. In view of this high correlation between grease and clean fleece weights of yearlings born from 1945 to 1955, the above regressions were considered to be satisfactory for the estimation of clean fleece weights of F1 and F2 animals born in 1938.

TABLE 3. — EFFECTS OF AGE ON THE WEANING WEIGHT OF LAMBS, 18-MONTH WEIGHT OF EWES AND YEARLING CLEAN FLEECE WEIGHT

	Weaning weight	18-month weight of ewes	Yearling clean fleece weight	
			Rams	Ewes
Number of years	18	12	11	11
Number of animals	4,863	881	444	987
Regression, lb./day	0.26*	0.11**	0.03**	0.01**
Correlation coefficient	0.26	0.09	0.26	0.13
Heterogeneity of regression	**			**
Number of years regression non-significant	4			6
Number of years curvilinearity of regression significant	3			1

*, **Significant ($P < 0.05$ and 0.01, respectively)

TABLE 4. — WEIGHTED MEAN DIFFERENCES IN PERFORMANCE OF ROMNELETS OUT OF 6-YEAR-OLD AND 2-YEAR-OLD EWES, COMPUTED ON AN INTRA-GENERATION BASIS

	Birth weight	Weaning weight	18-month weight of ewes	Yearling clean fleece weight
Number of years	13	13	9	11
Number of animals:				
from 6-year-old ewes	387	217	26	70
from 2-year-old ewes	482	293	47	100
Difference, 6-year minus 2-year, lb.	0.61**	2.74**	−2.71	−0.05

**Significant ($P < 0.01$)

As shown in Table 4, Romnelets out of 6-year-old ewes were 0.61 pound heavier at birth and 2.74 pounds heavier at weaning than those out of 2-year-old ewes, but the age-of-dam differences in yearling clean fleece weight and 18-month weight of ewes were non-significant. In computing genetic trends in birth weight and weaning weight from F1 to F2, the generation means were adjusted to a constant age-of-dam basis.

Genetic Trends in Performance

The estimated mean generation differences in performance, with the numbers of animals and years used in the comparisons, are presented in Table 5.

The most striking feature of the genetic trends was the reduction in performance from F1 to F2. This is not surprising; crossbreds are frequently heterotic and, as indicated by Dickerson *et al.* (9), inbreeding effects following a cross are likely to be greater than those of later generations because of the greater initial heterozygosity and accompanying high level of performance. The work of Hazel and Terrill (14, 15, 16), Terrill, Sidwell and Hazel (28, 29, 30), Morley (19), Doney (10) and Ragab and Asker (23) showed that inbreeding has a depressing effect on body size and fleece weight.

TABLE 5. — ESTIMATED MEAN GENERATION DIFFERENCES IN BIRTH WEIGHT, WEANING WEIGHT, 18-MONTH WEIGHT OF EWES AND YEARLING CLEAN FLEECE WEIGHT IN THE ROMNELET SHEEP

Generation comparison	Birth weight			Weaning weight			18-month weight of ewes			Yearling clean fleece weight		
	Numbers of animals	Mean diff., lb.	Years in comparison	Numbers of animals	Mean diff., lb.	Years in comparison	Numbers of animals	Mean diff., lb.	Years in comparison	Numbers of animals	Mean diff., lb.	Years in comparison
F1-F2	390[1], 150	1.3**	1938	217, 103	7.5**	1938	106, 42	7.0**	1939	149, 71	0.6**	1939
F2-F3	439, 215	0.3*	1940-1946, excl. 1944	375, 165	0.9	1940-1946, excl. 1944	63, 17	−2.0	1943, 1947	47, 47	0.5**	1946, 1947
F3-F4	284, 320	−0.3	1943-1950, excl. 1945	231, 242	0.7	1943-1950, excl. 1945	15, 28	3.0	1947, 1948, 1951	25, 57	0.0	1947, 1948, 1949, 1951
F4-F5	420, 411	−0.1	1947-1952, incl.	297, 260	−0.6	1947-1952, incl.	55, 62	3.5	1949-1952, incl.	121, 125	−0.1	1948-1953, incl.
F5-F6	189, 357	0.3*	1951-1955 incl.	107, 259	−3.2**	1951-1955, incl.	26, 50	0.3	1952-1956, incl.	49, 129	−0.2	1952-1956, incl.
F6-F7	71, 32	0.6	1954, 1955	43, 24	−4.6*	1954, 1955	15, 10	−4.1	1955, 1956	24, 14	−0.1	1955, 1956

[1]390 F1 and 150 F2, etc.
*, **Significant ($P < 0.05$ and 0.01, respectively)

There was a further significant decrease in birth weight and clean fleece weight from F2 to F3. An upward trend in the later generations was shown for weaning weight, 18-month weight of ewes and yearling clean fleece weight, although only that for weaning weight was statistically significant. The role of selection as a possible factor influencing genetic trends will be the subject of a subsequent paper.

The influence of environment on yearly means of performance was illustrated by the finding that the highest average birth weight and the lowest average weaning weight for the flock during the period of breed development were recorded in 1955, the year when the flock had the lowest genotypic average in birth weight and, with the exception of the years when the F1 lambs were born, the highest genotypic average in weaning weight.

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THE ADDITION OF BUFFERS TO RUMINANT RATIONS

I. EFFECT ON WEIGHT GAINS, EFFICIENCY OF GAINS AND CONSUMPTION OF RATIONS WITH AND WITHOUT ROUGHAGE[1]

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ABSTRACT

A total of sixty-eight beef steers were used in three feeding trials to determine the effects of adding buffers to ruminant rations. The buffers used in these trials were sodium propionate and mixtures of sodium bicarbonate, potassium carbonate and calcium carbonate (as ground limestone). They were fed at levels varying from 2 to 9 pounds per 100 pounds of the concentrate ration. Data on feed consumption, weight gains and efficiency of feed conversion are presented.

The addition of buffers to a ration containing timothy hay fed *ad libitum* did not prove beneficial. Buffers at the highest level (9 pounds per 100 pounds) were detrimental in the hay-concentrate ration. When the hay was removed from the ration there were highly significant decreases in weight gains and T.D.N. consumption. These decreases were partially offset by the addition of buffers to the all-concentrate rations. The results may have a practical application in the feeding of low-roughage rations.

INTRODUCTION

Fifty years ago nutritionists were concerned with acid-base balance in animal nutrition (7) but this field became neglected in the following years. The early work has been reviewed by Green (8), Mitchell and McClure (11) and others. Interest in the acid-base balance of the ruminant ration has recently been revived by the work of Matrone *et al.* (9 and 10), Essig *et al.* (6) and Thacker (15).

Much interest has been centred recently on feeding all-concentrate rations. Reid *et al.* (13) noted that sheep fed high starch rations developed very low rumen pH associated with an accumulation of lactic acid. When this occurred the animal would go off feed for several days. The low pH could be prevented by the administration of sodium carbonate. The investigators postulated that the high pH levels favoured the growth of bacteria which convert lactic acid to the volatile fatty acids. Matrone *et al.* (10) suggested that the beneficial role of sodium or potassium as salts of metabolizable anions was associated with the increased buffering capacity of the rumen contents.

It has been suggested (4) that the beneficial effect of alfalfa ash when added to high-starch, low-ash rations was due to its alkaline nature. Nicholson *et al.* (12) found that the addition of the carbonate or bicarbonate salts of calcium, magnesium, sodium and potassium, to a ration of corn cobs, corn starch and soybean oil meal supplemented with urea, minerals and vitamins, improved feed consumption and tended to improve growth. Alfalfa hay or alfalfa ash supplements gave smaller responses that were not statistically significant.

Sodium propionate could also serve as a non-toxic source of fixed base.

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[1]Contribution No. 110, Division of Animal and Poultry Science, Research Branch, Canada Department of Agriculture, Nappan, N.S.

There is evidence indicating that a high ratio of propionic to acetic acid production in the rumen leads to increased efficiency of feed utilization (1, 14). The addition of sodium propionate to the ration might give a similar response.

Three steer feeding trials have been conducted at the Experimental Farm, Nappan, Nova Scotia, to further clarify the effect of adding salts of metabolizable anions to ruminant rations. The feed consumption, weight gains and efficiency of feed conversion of the steers on these trials are presented in this paper. The results obtained are discussed in relation to feeding all-concentrate rations.

EXPERIMENTAL PROCEDURE

Trial 1

Forty 20-month-old Hereford steers were used in a feeding trial lasting 110 days. The steers, of similar breeding, were obtained from Western Canada and treated uniformly during the year preceding the experiment. The animals were ranked according to weight and the list divided in ranking order into four lots of 10 animals each. One member of each lot was then assigned at random to a pen so that each pen contained 4 animals totalling approximately the same weight. Each of the concentrate rations, numbers 1 through 5 as shown in Table 1, was randomly assigned to two of the pens. Good quality timothy hay was fed to all animals in addition to the concentrate rations. Two animals in each group were implanted with 24 milligrams of stilbestrol at the beginning of the trial.

Each group of 4 animals was housed in a separate pen in a pole barn. Each pen was provided with individual feeding mangers, an electrically heated water bowl and an outdoor exercise yard. The animals were tied up in their mangers for approximately 2 hours twice daily and allowed all the feed they would consume during these feeding periods. Feed was not available at other times. Wood shavings were used for bedding.

The steers were weighed on 2 consecutive days at the beginning of the experiment and once every 28 days thereafter, except that the last period was only 26 days. Records were kept of the individual feed consumption. The rations were sampled and proximate analyses conducted according to official A.O.A.C. methods. At the termination of the experiment the animals were slaughtered. Carcass weights and Standard Canadian carcass grades were obtained on all animals. The kidneys of animals that received Rations 1 and 4 were examined for evidence of pathological damage.

Trial 2

Twenty 1-year-old Shorthorn steers were divided into four groups (A, B, C and D) totalling approximately the same initial weight, by a procedure similar to that described under Trial 1. One member from each group was assigned at random to one of five pens. The pens were equipped with water bowls and individual feeders but outside exercise yards were not provided. Wood shavings were used for bedding.

The animals were tied up twice daily, as in Trial 1, for feeding. The animals in Group A were fed Ration 1 (Table 1) plus all the timothy hay

TABLE 1.—COMPOSITION OF THE CONCENTRATE RATIONS

Ration No.	1	2	3	4	5	6
Ingredients in pounds						
Ground oats	44.25	44.25	44.25	44.25	44.25	44.25
Ground barley	44.25	44.25	44.25	44.25	44.25	44.25
Linseed oil meal	10.0	10.0	10.0	10.0	10.0	10.0
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Trace-mineralized salt	0.5	0.5	0.5	0.5	0.5	0.5
Special minerals[1]	—	3.0	6.0	9.0	—	7.2[2]
Sodium propionate	—	—	—	—	2.0	—

[1]The special mineral mixture consisted of 2 parts ground limestone, 2 parts $NaHCO_3$, and 1 part K_2CO_3 by weight

[2]Contained equal parts of ground limestone and sodium bicarbonate

TABLE 2.—AVERAGE PROXIMATE COMPOSITION OF CONCENTRATE RATIONS AND HAY

	Protein	Fibre	N.F.E. and ether extract	Ash
	Per cent on as fed basis			
Ration 1	13.85	5.61	66.96	3.90
Ration 2	13.06	5.98	65.47	6.07
Ration 3	12.84	5.39	64.51	7.89
Ration 4	12.53	5.37	62.36	10.24
Ration 5	13.63	5.54	65.99	4.61
Ration 6	12.69	5.74	63.37	8.19
Timothy hay	6.74	29.22	52.94	5.34

they would consume during the feeding periods. Group B was fed Ration 1 without hay. Group C received Ration 6 without hay, and Group D was given Ration 4 without hay. Each animal in Groups B, C and D was fed a small allowance of hay at the beginning of the trial but this was gradually reduced so that at the end of the first week these animals were on an all-concentrate ration.

The steers were weighed on 2 consecutive days at the beginning of the experiment and at 28-day intervals thereafter. The trial was continued for 84 days, at which time the steers were turned out to pasture.

Trial 3

Eight Hereford steers similar to those in Trial 1 were used in a 91-day feeding trial. The animals were allocated into two groups of approximately equal weight and were kept in stanchions in a standard type dairy barn. One group was fed Ration 1, while the other group was fed Ration 4 (Table 1). Hay was not fed. Individual feed consumption was recorded and the animals were weighed at 30-day intervals. At the end of the experiment the animals were slaughtered but carcass weights and grades were not obtained. The kidneys of these animals were examined for pathological lesions.

TABLE 3.—THE EFFECT OF ADDING BUFFERS TO A HAY-CONCENTRATE FATTENING RATION ON THE WEIGHT GAINS, FEED CONSUMPTION AND EFFICIENCY OF GAINS OF HEREFORD STEERS (TRIAL 1)

Ration		1	2	3	4	5[1]	Standard error (5 d.f.)	Significance[2] of differences
Initial weight	lb.	680	675	677	678	677	—	—
Final weight	lb.	907	881	903	868	904	—	—
Daily gain	lb.	2.07	1.87	2.06	1.73	2.07	0.07	4<1, 3, 5*
Daily concentrate intake	lb.	10.18	10.27	10.45	10.33	9.86	0.11	5<2*, 4*, 3*
Daily hay intake	lb.	8.18	7.95	8.08	7.95	8.11	—	—
Daily T.D.N. intake	lb.	11.94	11.70	11.75	11.37	11.55	0.14	1>4*
Lb. T.D.N. per lb. gain		5.80	6.28	5.84	6.69	5.58	0.21	4>5, 1, 3*
Dressing percentage		51.8	52.2	52.2	51.6	52.7	0.42	—

* = $P<0.05$

[1]One steer had to be withdrawn from Ration 5 due to an infection. The results are averages of the remaining 7 animals. Data on other rations are average of 8 animals.
[2]Significance determined by Duncan's Multiple Range Test

RESULTS

Trial 1

The data from Trial 1 were analysed statistically using a split-plot design. Rations were considered "main-plots" and the mean squares for "pens within rations" with five d.f. were used for calculating the standard errors of means shown in Table 3. The means were compared by the use of Duncan's Multiple Range Test (5) using the above standard errors. The stilbestrol treatment was considered as "sub-plots". The mean squares for the interactions between rations and stilbestrol treatment (with four d.f.) was calculated and found not to be significant in any case. The remaining variation with 25 d.f. was used as an error term for testing the effect of the stilbestrol treatment.

The proximate analyses of the rations are given in Table 2. The T.D.N. intakes shown in Tables 3, 4 and 5 were calculated from the proximate analyses data in Table 2 using Morrison's digestibility coefficients. The results of Trial 1 are summarized in Table 3. The weight gains obtained with Ration 5, which contained sodium propionate, equaled or exceeded those obtained with the other rations. The concentrate consumption on this ration, however, was lower than on any of the other rations (significantly lower than Rations 2, 3 and 4). This combination of rapid gains and low feed intake on the ration containing sodium propionate resulted in greater efficiency of feed conversion expressed as pounds of T.D.N. required per pound of gain in weight, statistically significant only over Ration 4 ($P < 0.05$). The gains and efficiency of feed conversion on the control ration (Ration 1) and Ration 3, which contained an amount of buffers intermediate between Rations 2 and 4, were close to those obtained on Ration 5 and significantly higher than on Ration 4.

The T.D.N. intake on Ration 1 was significantly higher than on Ration 4. None of the other differences in hay, grain or T.D.N. consumption between the control ration and those containing the inorganic buffers (Rations 2, 3 and 4) reached statistical significance at the 5 per cent level of probability. The data indicate, however, that the animals attempted to increase their feed intake to compensate for the addition of the inorganic buffers. This increase was not sufficient to overcome the diluting effect of the buffers and T.D.N. intake was lower on the buffer-containing rations. None of the rations fed influenced hay consumption significantly.

There were no significant differences due to the treatments imposed on dressing percentage or carcass grade of the steers.

The post-mortem examination of the kidneys revealed lesions in one steer on Ration 1 and 6 steers on Ration 4. The lesions consisted of small areas of fibrosis in the kidney extending from the surface under the capsule through the cortical portion and appeared to terminate at the medullary portion of the kidney.

The steers implanted with 24 milligrams of stilbestrol at the beginning of the trial had highly significant faster gains (0.33 pounds per day) and greater efficiency of feed conversion. There were no interactions with the buffers and no significant differences in feed intake due to the stilbestrol implants.

TABLE 4.—THE EFFECT OF REMOVING ROUGHAGE AND ADDING BUFFERS TO A FATTENING RATION FOR SHORTHORN STEERS (TRIAL 2)

Group		A	B	C	D		
Treatment		Ration 1 plus hay	Ration 1 no hay	Ration 6 no hay	Ration 4 no hay	Standard error (12 d.f.)	Significance[2] of difference
Initial weight	lb.	465	474	463	473	—	—
Final weight	lb.	612	539	554	553	—	—
Daily gain	lb.	1.76	0.77	1.09	0.95	0.13	A>B, D, C**
Daily concentrate intake	lb.	8.31	7.90	9.50	8.02	0.42	C>B, D*
Total hay intake per steer[1]	lb.	360.8	30.9	32.2	53.6	—	—
Daily T.D.N. intake	lb.	8.49	6.13	6.94	5.92	0.30	A>B, C, D**; C>D*
Lb. T.D.N. per lb. gain		5.04	15.69	6.58	6.65	4.05	—

** = P<0.01 * = P<0.05

[1]It was necessary to feed some hay at the beginning of the experiment to stimulate grain consumption. See text.
[2]Significance determined by Duncan's Multiple Range Test

Trial 2

The sources of variation separated in the statistical treatment of the data from Trial 2 included pens with four d.f., rations with three d.f. and their interaction with 12 d.f. The mean squares for the latter were used to calculate the standard errors of the means given in Table 4 and in the application of Duncan's Multiple Range test. The results of Trial 2 are presented in Table 4. To stimulate satisfactory consumption of the concentrate ration it was necessary to continue feeding a small amount of hay for 1 month to 1 animal in Group B, and 2 animals in Group D. The total hay eaten by these animals is included in the averages shown in Table 4. One animal in Group D refused to eat significant amounts of Ration 4 but consumed a mixture of Ration 4 and 6. The data from this steer are included in the averages given in Table 4 for Ration 4.

The average daily gain, T.D.N. consumption and feed efficiency were greater for the animals fed both hay and concentrate (Group A). Concentrate consumption was significantly higher on Ration 6 (Group C) than on Ration 4 and Ration 1 fed without hay. The low rate of gain and feed efficiency for Group B was due mainly to 1 steer and the differences between this group and the others, while quite large, were not statistically significant.

Trial 3

The response to the addition of buffers by the larger Hereford steers in Trial 3 was greater than with the younger Shorthorn calves. The data are summarized in Table 5. The steers receiving the buffered ration consumed significantly more feed. The difference in average daily gain, while

TABLE 5.—THE EFFECT OF ADDING BUFFERS TO AN ALL-CONCENTRATE FATTENING RATION ON FEED CONSUMPTION, WEIGHT GAINS AND EFFICIENCY OF GAINS (TRIAL 3)

Treatment		Ration 1	Ration 4[1]	Standard error (5 d.f.)	Significance of difference
Initial weight	lb.	666.5	678.3	—	—
Final weight	lb.	762.5	843.0	—	—
Daily gain	lb.	1.06	1.71	0.36	—
Daily concentrate intake	lb.	9.94	14.01	0.69	1<4**
Daily T.D.N. intake	lb.	8.25	10.79	0.56	1<4*
Lb. T.D.N. per lb. gain		7.78	6.31	—	—

** = P<0.01 * = P<0.05

[1]One steer was accidently killed when taking rumen samples. Averages on Ration 4 for the three remaining animals.

large (0.65 pounds), was not statistically significant due to the small numbers involved in this trial. Kidneys from the animals on this trial were examined at the Animal Pathology Laboratory, Sackville, New Brunswick. Kidneys from both groups showed slight gross and microscopic changes which could be indicative of toxicity. Kidneys from 2 animals on the control ration showed lesions similar to those associated with leptospirosis.

DISCUSSION

The addition of buffers to a ration containing timothy hay did not prove beneficial (Trial 1). In fact, the addition of 9 per cent* buffers to the control ration significantly decreased gains, T.D.N. consumption and feed efficiency. Similar results have been reported for the addition of alfalfa ash to rations containing small amounts of hay (2, 3, 12, 16). The addition of a small amount of sodium propionate to the control ration tended to reduce T.D.N. consumption and improve feed efficiency. These differences approached statistical significance at the $P < 0.05$ level of probability.

Removing the hay from the control ration (Trial 2) significantly reduced ($P < 0.01$) weight gains and T.D.N. consumption. The addition of 7.2 per cent of a mixture of ground limestone and sodium bicarbonate to the all-concentrate ration improved feed consumption significantly and tended to improve gains and feed efficiency. Results with this ration did not equal those obtained by feeding hay with the concentrate. The addition of potassium carbonate to make a total of 9 per cent buffers (Ration 4) in the ration gave results intermediate between the 7.2 per cent level of buffers (Ration 6) and the control all-concentrate ration. There was evidence to indicate that the animals found the potassium carbonate unpalatable. It should be noted that in Trial 1 the 6 per cent level of a buffer mixture containing 2 parts limestone, 2 parts sodium bicarbonate, and 1 part potassium carbonate tended to give better results than 9 per cent of the same buffer mixture (not statistically significant). This could be an indication that the 9 per cent level of buffers was too high and consequently part of

*For convenience in reference throughout the discussion the levels of buffers are referred to as "per cent" rather than pounds per 100 pounds of basal ration.

the difference between Groups C (7.2 per cent buffers) and D (9 per cent buffers) in Trial 2 may be due to level of buffers and part due to the potassium carbonate. The addition of 9 per cent buffers in Trial 3 resulted in a 40 per cent increase in feed consumption on an all-concentrate ration. It also tended to improve daily gain and feed efficiency. Unfortunately, lower levels of buffers were not tested in this trial.

Some evidence of kidney damage was found in Trials 1 and 3 on post-mortem examination. The damage was found in animals that received hay as well as those on the all-concentrate ration, and on the control ration as well as the buffered rations. However, the addition of buffers seemed to accentuate the injury in Trial 1. Because the injury occurred on all types of rations used, its cause will require further study.

On all three trials the animals consumed considerable amounts of the wood shavings used for bedding. This was more evident in Trials 2 and 3 where the animals were fed all-concentrate rations. Pine shavings seemed to be preferred over other softwood shavings. In Trials 2 and 3 some difficulty was encountered with animals on the all-concentrate rations going off feed. They could be induced to resume eating the assigned ration by feeding a small amount of hay for several days. This difficulty was largely overcome by the addition of buffers to the ration.

Additional trials are now in progress to investigate the effect of the buffers on intra-ruminal pH and volatile fatty acid production.

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AN ECONOMICAL LABORATORY MOUSE COLONY[1]

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ABSTRACT

An economical and effective procedure for the production and maintenance of a laboratory mouse colony is described. It features the use of common and readily available structural materials which can be assembled and dismantled with minimal effort and skill. Ventilation, lighting, sanitation, feeding and watering techniques are described. Ten years of experience with this management procedure has shown that animals of high quality can be produced and maintained at minimal cost.

INTRODUCTION

The laboratory mouse is widely used as an experimental mammal for teaching and research purposes. The extensiveness of its use, particularly in smaller institutions, has been severely limited by the financial outlay necessary for the establishment and maintenance of colonies of this rodent. The purpose of this communication is to present in outline a housing and management procedure which has been found to be satisfactory in that it produces and maintains laboratory mice of a high quality at minimal cost for initial establishment and subsequent maintenance.

MANAGEMENT

Caging

The basis of this caging system is the use of common structural materials which can be rapidly assembled and dismantled by relatively unskilled technicians. The three basic parts of the caging are: 1) Dexion Steel Angle[4] ($1\frac{1}{2}$" x $2\frac{3}{8}$"); 2) standard expanded metal or crete as used for lathing for plaster or stucco[5]; and 3) a common circular metal dish-pan[6].

A typical cage and rack assembly is shown photographically in Figure 1 and as a dimension drawing in Figure 2. The caging illustrated is of a size particularly suited to our specific needs. It should be stressed that one of the important advantages of this system is that it can be set up in almost any form to suit local conditions. The cage frame is made of Dexion angle and supports expanded metal shelves. The bottom shelf supports the first layer of mouse pans. The subsequent sheet of expanded metal provides the lid for the cages below it and the support for the cage above. It has been found convenient to have five layers of mouse pans from the bottom before a second fixed shelf supported by dexion angle is inserted. Above this middle fixed shelf it is possible to have three, four, five or six additional layers of pans supported and lidded by the expanded metal shelves. The top layer of expanded metal which provides the lid for the top-most layer of pans serves as a convenient storage space for clean pans bedded with wood shavings, that are used as each row of cages is changed. In a typical cage rack we have found it convenient to have nine layers of mouse pans in a rack, with alternating rows of five and six pans.

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[2]Geneticist, Department of Paediatrics.
[3]Professor, Division of Animal Science.
[4]F.T.S. Limited, Vancouver, B.C.
[5]Standard Steel Crete (¼-18-50 Standard Mesh). The Pedlar People Ltd., Oshawa, Ont.
[6]Dimensions: Base 9-inch diameter; top 14-inch diameter; height 5 inches.

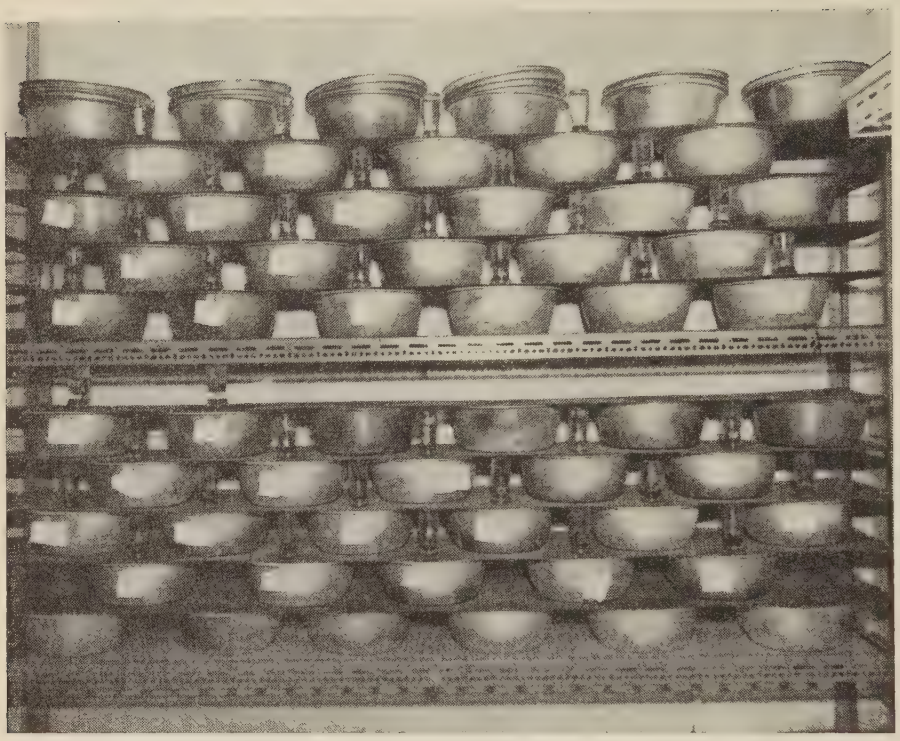

FIGURE 1. A typical cage rack and assembly.

The circular pan with sloping sides facilitates handling and cleaning, since up to 20 pans can be nested for transport. The pans are cleaned using a hot (180°F.) solution of 1 per cent trisodium phosphate as a cleaning agent. An automatic washer is helpful though not absolutely necessary, but it is essential that the dirty pans be cleaned thoroughly before they are re-used. A standard milk bottle case washer has given satisfactory service for pan washing in our units for the past 10 years. The arrangement of these circular pans in the manner outlined above is most desirable and has several distinct advantages. These are:

1) It provides for space between the curvature of two adjacent pans for the placement of the water bottle for the pan below, and hence saves considerable space and at the same time it provides for adequate ventilation.
2) It permits easy inspection of the pans and their occupants with a minimum of disturbance to the latter.
3) Since each pan essentially functions as a drawer, it can be readily pulled forward when necessary in order to add or remove feed or animals.

A rack similar to the one shown in the figures has space for approximately 50 mouse pans with storage space on the upper shelf for 50 replacements containing bedding. The floor space occupied by the rack measures 18 inches by 96 inches and hence each actual mouse pan requires slightly

less than 0.25 square feet of floor area. With an occupancy rate of 12 adult mice per pan or a total of 600 mice, this caging and rack system accommodates 50 mice per square foot of floor space. In a room with a ceiling height of 9 feet, more than 5 mice per cubic foot can be housed on a floor area 18 inches by 96 inches.

In situations where a series of such racks and cages are used, we have found it convenient to arrange the cages as shown in the key plan in Figure 2. In this case a room 9 feet by 11 feet with a ceiling 9 feet in height accommodates 225 cages capable of holding about 2,600 mice if 12 mice are housed in each pan. It is possible to accommodate 24 mice per square foot of room floor space or 2.4 mice per cubic foot of room volume. In the set-up shown in the key plan, the passageway between racks is approximately 36 inches wide. This allows adequate space for feeding, watering and pan changing. More efficient use of room space can, of course, be achieved by having two cages in the centre of the room placed back to back, so that the two passageways can serve four racks rather than three as shown in the key plan. The number of mice housed per unit of floor area is in part determined by the frequency of cage cleaning. When 15 animals are housed per cage, cleaning should be carried out at 48-hour intervals. With fewer animals, the interval between cleaning can be extended.

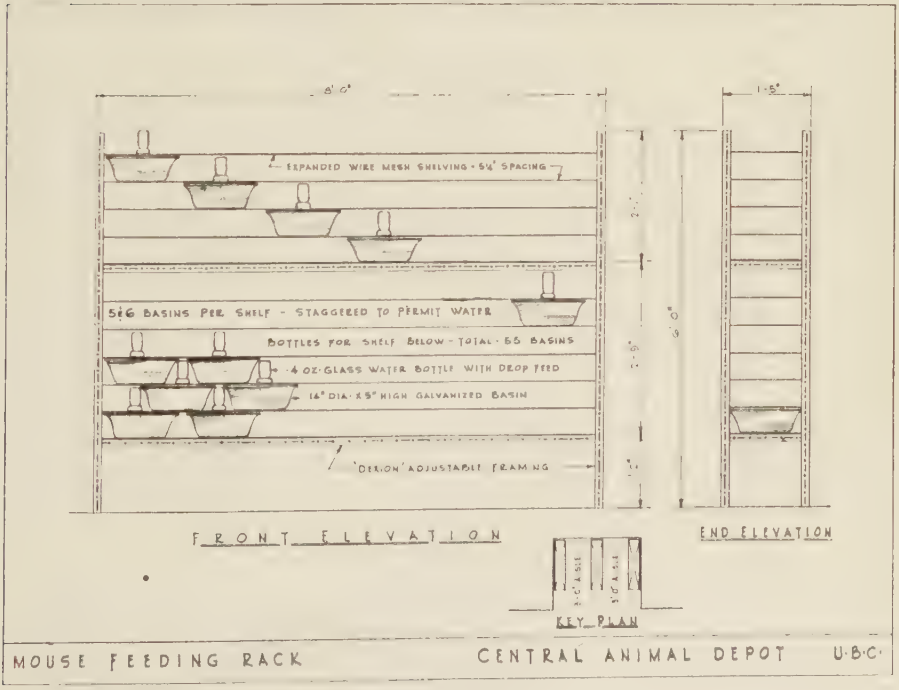
EXPANDED WIRE MESH SHELVING - 5¼" SPACING
5¢G BASINS PER SHELF - STAGGERED TO PERMIT WATER
BOTTLES FOR SHELF BELOW - TOTAL - 55 BASINS
4 OZ. GLASS WATER BOTTLE WITH DROP FEED
14" DIA. X 5" HIGH GALVANIZED BASIN
'DEXION' ADJUSTABLE FRAMING
FRONT ELEVATION
END ELEVATION
KEY PLAN
MOUSE FEEDING RACK
CENTRAL ANIMAL DEPOT
U.B.C.

FIGURE 2. Dimension drawing of mouse pan rack and pan arrangement.

Ventilation

An influent air supply thermostatically controlled to 75°F. and having a relative humidity of 40 per cent is provided. Under these circumstances 20 air changes per hour provided by a 300 c.f.m. fan ensures adequate ventilation. Perhaps of greater importance, this rate of air exchange at this relative humidity ensures that the room environment and the pan bedding remain relatively dry. This system of ventilation provides 0.1 cubic feet of air per mouse per minute with the cage arrangement and room shown in Figure 2. Where climatic circumstances permit, it is desirable to exhaust the entire influent air supply. Where this is not possible it is imperative that adequate humidity control be provided.

In the room illustrated in Figure 2 the influent air supply is provided through a single wall louvre 5 inches x 11 inches situated at the midpoint of one of the walls at a height of 12 inches above the floor. The conditioned air passes through this louvre at a speed slightly in excess of 600 linear feet per minute (8 m.p.h.). The air movement in the room itself is at the rate of 3 linear feet per minute (.04 m.p.h.). This provides for adequate ventilation without drafts or excessive air turbulence, since the louvre is located below the lowest row of mouse pans.

Lighting

Lighting requirements are of necessity determined by the type of work being conducted in an animal room and by the colour and finish on the wall, floor and cage surfaces. For routine mouse breeding and production purposes, a light intensity of 0.8 foot candles in the mouse pans has proven to be adequate.

Watering

In this system of caging, water is most easily provided from an inverted, 4-ounce bottle closed by a one-hole No. 8 rubber stopper through which is inserted a short (8-cm.) straight length of Pyrex glass tubing (7 mm. i.d.). The tubing is inserted through the expanded metal pan lid so that the rubber stopper rests on the lid and the bottle stands vertically above the mouse pan. The straight water tube greatly facilitates cleaning and disinfection in contrast to the bent tube inserted through the front of the more conventional mouse cages. A bottle, e.g., a milk bottle, with a wide mouth is desirable to ensure vertical stability and to facilitate filling and cleaning. One man can rinse and refill 400 such bottles per hour. If the water supply is of high quality and the water is replaced daily, such bottles require washing at 14-day intervals. In the event that recurrent sub-acute infection is present in the mouse colony, more frequent washing and sterilization are obviously necessary.

Feed

A large number of commercially formulated mouse feeds are available. The present status of knowledge on the nutritive requirements of the mouse is not sufficient to permit the formulation of mouse diets on a completely rational basis.

TABLE 1.—PERTINENT DATA ON U.B.C. MOUSE RATION NO. 6-60

Ration formulation			Ration composition		
Ingredient	Per cent	lb. or ton	Nutrient	Per lb.	Per cal.[1]
Ground wheat	35.0	700	Moisture	0.10 lb.	——
Ground barley	20.0	400	Protein (N x 6.25)	0.24 lb.	80 mgm.
Fish meal (herring 70%)	15.0	300	Fat	0.05 lb.	16 mgm.
Soya meal (50%)	7.5	150	Fibre	0.04 lb.	——
Skim milk powder (spray)	7.5	150	Calcium	0.02 lb.	6.4 mgm.
Alfalfa leaf meal	5.0	100	Phosphorus	0.01 lb.	3.4 mgm.
Molasses (cane)	5.0	100	Vitamin A	4500 i.u.	3.4 i.u.
Animal fat (BHT stabilized)	2.5	50	Vitamin E	6.5 mgm.	4.8 mcgm.
Irradiated yeast	0.25	5	Riboflavin	2.0 mgm.	1.5 mcgm.
Steamed bone meal	1.0	20	Niacin	22.0 mgm.	16.5 mcgm.
Iodized salt	1.25	25	Pantothenic acid	6.0 mgm.	4.6 mcgm.
			Choline	0.6 gm.	0.5 mgm.
	100.00	2000	Folic acid	0.6 mgm.	0.4 mcgm.
			Arginine	5.0 gm.	2.5 mgm.
			Methionine	2.5 gm.	1.9 mgm.
			Cystine	1.8 gm.	1.3 mgm.
			Lysine	8.0 gm.	6.9 mgm.
			Tryptophane	1.6 gm.	1.6 mgm.

[1]Assumes 1300 calories of metabolizable energy per pound as fed

The diet formulation presented in Table 1 has given satisfactory results and has not required supplementation with any other feed. The formulation was evolved over a number of years, using as a criterion of adequacy the ability to support growth, reproduction and lactation in successive generations of animals. It is prepared as a ¾-inch diameter cylindrical pellet, 1 inch in length. These pellets are fed directly in the mouse pans. (On the average a mature mouse consumes 4-5 grams of the diet *per diem*). The amount of feed placed in a pan at any one feeding and the interval between pan changes will of course depend on the number of animals housed per pan.

PERFORMANCE

The ultimate test of the efficacy of any management plan can be gauged by the quality of the animals it produces. Quality in a small mammal can be evaluated in a number of ways, such as over-all conformation, coat lustre, reproductive performance, growth rate, etc. Prior to 1958, the mouse production colony in the Central Animal Depot, University of British Columbia, was maintained in a manner that did not readily lend itself to the proper collection of data and the development of adequate records for these parameters. However, the general impression prevailed that the management plan produced an animal of extremely good quality. In September, 1958, a colony of several inbred strains was added to this production colony. These animals had been maintained for several years under management conditions other than those outlined in this report. During the intervening 2 years, detailed records have been maintained continuously on reproductive performance of these small inbred units. In addition, for a period of 3 months at the end of the first year, growth curves from birth to 11 weeks of age were obtained on a representative sample of all strains. On the basis of the criteria of reproductive performance, growth, over-all appearance and ability to withstand subsequent stresses associated with long-distance transport, we believe that the mice produced under the conditions described above are of excellent quality. Records on the performance of these inbred strains are being maintained through successive generations and will be reported upon in detail at a later date.

DISCUSSION

The system of housing and management outlined in this report contravenes in several respects the standards set forth by the Committee on Standards of the Institute of Laboratory Animal Resources (1). Probably the most controversial feature of the system is the direct feeding of the pelleted food in the mouse pans. It is generally recommended that feed should be placed in some type of special feeder in order to prevent contamination of the food by excreta. This recommendation is presumably designed to prevent the recycling of any pathogens that might be present in the faeces or urine. However, three facts should be pointed out: 1) the design of most feeding devices fails to satisfy this objective; 2) coprophagy assures that recycling of faecal material occurs despite the most dedicated efforts to prevent it, and 3) the only causal agent for intermittent disease

in an animal colony must be the presence of an infectious agent. Special feeding devices by themselves cannot be expected to eliminate or control such agents. In fact, some of the special feeding devices in use present serious sanitation problems because of their structural complexities.

The colonies maintained in the fashion outlined above have remained free of any serious epizootic over the past 10 years. This has been achieved using simple and inexpensive materials and by the development of common-sense rules for the guidance of the animal attendants. In most instances, breeding pairs, if they are not crowded, will arrange their pan into three separate areas and will use these areas for nesting, feeding and defaecating. Under these circumstances the food is usually free of appreciable soiling. When pans are changed, any soiled food present in the old pan is discarded. If there is evidence of abnormal faecal contamination, the mouse responsible is removed from the colony. If the animal is considered to be indispensable, it is isolated and an appropriate therapeutic procedure is implemented.

In conclusion, it should be stated that we do not deny the merit of the elaborate rules and regulations proposed by the Committee on Standards of the Institute of Laboratory Animal Resources. However, such recommendations tend to discourage the use of the laboratory mouse by those in small institutions with limited financial and physical resources. For individuals who are forced to operate under such circumstances, we believe that the methods outlined in this report, for the establishment and maintenance of a small, inexpensive mouse colony, have some value.

ACKNOWLEDGEMENT

The successful development and operation of our mouse colonies using the techniques described above are largely due to the unfailing co-operation of Cliff Harvey, Senior Animal Technician.

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A COMPARISON OF FIXED VS. ADJUSTED STOCKING WITH YEARLING BEEF CATTLE ON PERMANENT EASTERN ONTARIO PASTURES[1]

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ABSTRACT

A comparison of animal gain, total digestible nutrients (TDN) calculated from animal requirements for maintenance and gain, and dry matter (DM) production under fixed vs. adjusted stocking management of native pastures was carried out over a 4-year period, 1954 to 1957. Total gain, average daily gain (ADG) and TDN were markedly higher for the adjusted stocking treatment in all years. DM production (cage clippings) did not differ between treatments. Year differences were very marked in total gain, ADG and DM production. This appeared to be related to season, temperature and rainfall. Lowest total gain and ADG occurred during the two cooler seasons (1954 and 1956) which had the highest average rainfall. The relationship between DM production and total gain was very low. The highest DM production occurred in 1956 when the total gains were the second lowest. Calculations based on livestock response suggest that the nutritive quality of the herbage was higher for both treatments during the relatively warm dry years (1955 and 1957), and that forage consumed from plots stocked by the adjusted method was of higher quality than from those stocked by the fixed method. TDN was much more efficiently used for animal gain on the adjusted plots than on the fixed stock plots in 3 years out of 4. Treatment had no marked influence on sward composition over the 4-year period.

INTRODUCTION

"With common pasture mixtures, up to 80 per cent of the season's growth is produced before the end of July" (5). The growth rate usually declines sharply during midsummer, increases during the early fall and drops again with falling temperatures in October.

One common method of utilizing the excess herbage produced during the early part of the pasture season is by conserving it as hay or silage. This is not always feasible for areas remote from the winter feeding premises or for operators who feed cattle during summer only and dispose of them in the fall. In these types of operation, herbage conservation as hay or silage is not desired.

Another method of utilizing the herbage during its peak growing periods is to adjust the number of cattle so that the extra grass is consumed when it is most nutritious. A disadvantage is that appreciable numbers of animals must be removed in midsummer when alternative pasture is relatively scarce. By stocking at a slightly less intense but fixed rate throughout the pasture season a considerable portion of the forage produced during the spring is not immediately utilized but provides a reserve for the remainder of the normal grazing season.

Linehan (4) states that "up to certain limits the more herbage present on the sward the higher will be the rate of growth". The resulting higher DM production might offset quality losses if cattle would eat the more mature forage.

[1]Contribution No. 61, Animal Research Institute, Research Branch.

In ranching areas of Western Canada much of the native forage is allowed to "cure" on the stem during early summer for subsequent grazing in late summer, fall and even throughout most of the winter when snow covering is dispersed by Chinook winds (6, 7). This mature forage provides a high proportion of the total seasonal intake of beef animals and is an integral part of many ranch operations. A number of non-native grasses such as smooth brome grass, *Bromus inermis*, and crested wheatgrass, *Agropyron cristatum*, do not provide forage of adequate feeding value when cured on the stem (7).

It was of considerable interest to determine if some of the forage species common to permanent pastures in Eastern Canada possess "curing" properties so that matured forage can provide a reserve for subsequent grazing. Hence, two methods of grazing management:

(a) stocking at a fixed rate throughout the season; and

(b) stocking at a level corresponding to current herbage production, were compared with respect to their effect on carrying capacity, animal gain, forage production and composition of the sward.

PROCEDURE

The experimental area consisted of three 4-acre fields. The fields had been in sod since 1911 and had been used in a grazing experiment comparing fertilizer treatments for the 16-year period preceding 1954. These treatments were as follows: Field 1 — 600 pounds of 20 per cent superphosphate every third year; Field 2 — as for Field 1, plus 100 pounds muriate of potash; Field 3 — as for Field 2, plus 100 pounds sulphate of ammonia applied annually. The fertilizer treatments were continued throughout this experiment.

Each field was sub-divided into two 2-acre plots and plots within fields were allotted to fixed or adjusted treatments at random. The plots were grazed for four seasons, 1954 to 1957 inclusive (Table 1). Animals were placed on pasture similar to the experimental plots for 1 week prior to being placed on experiment in order to acclimatize them to pasture conditions. They were then divided into six similar groups, balanced as to sex, weight and breeding. Each group was allotted at random to the experimental treatments. Intensity of stocking for the fixed treatment was based on the previous 16-year average carrying capacity. Three animals were allotted for the duration of the pasture season to each fixed grazing replicate.

Animal numbers on the adjusted replicates varied from 5 to 6 at the beginning of the grazing season, depending on the weight of the animals and herbage growth rate. Initial grazing of the experimental plots was begun when the grass was from 4 to 8 inches in height. The animals were weighed every 14 days. Removal of animals from adjusted plots usually corresponded with regular period weigh dates. Otherwise for inter-period removal, animal weights were recorded and calculated separately. Animal numbers on the adjusted plots were reduced as flush spring growth diminished. Later in the season animal numbers were reduced as the rate of gain decreased.

TABLE 1. — GENERAL INFORMATION ON EXPERIMENTAL ANIMALS AND GRAZING SEASON

Year	Treatment	Av. starting weight (lb.)	Av. no. animals per acre	Description of animals	Starting date	Length of grazing season (days)
1954	Fixed	561	1.50	Shorthorn steers and heifers	May 21	147
	Adjusted	563	1.34	C.E.F. herd		147
1955	Fixed	569	1.50	"	May 18	120
	Adjusted	571	1.38			120
1956	Fixed	606	1.50	"	June 1[1]	140
	Adjusted	623	1.66			140
1957	Fixed	519	1.50	*Hx(BxH) Hx(BxS) Hx(BxA)	May 15	133
	Adjusted	530	1.91			107

*H = Hereford B = Brahman S = Shorthorn A = Angus

[1]Experiment delayed until June 1, due to retarded grass growth during a cool, wet spring.

The cattle were sprayed once monthly with a residual fly spray (Methoxychlor) which provided reasonably good protection from flies. Water was supplied from a creek traversing all fields. Salt and bonemeal were available at all times and artificial shade (wood construction 8 feet in height) was provided on fields lacking natural shade.

Forage dry matter (DM) yields were measured by the direct method using eight to ten 1-square yard wire cages per acre. These were distributed at random over the plots and the covered areas clipped four to five times each season. After each clipping the cages were moved to a fresh location which was clipped prior to placing the cage.

The botanical composition of the sward was determined by the quadrat method in June 1954 and July 1957. The areas selected for analysis included three strips (sets) about 16 paces broad across all replicates, one at each end and one in the centre of the plots. Sampling was by simple quadrat 20 centimetres to the side. Twenty-five placements of this quadrat were made in each field in each set by random throwing of the frames. These were read in sequence in five tours back and forth across the six fields. Readings were taken whether the quadrats fell on closely grazed areas or on tall growth but quadrats falling on manure or stones were thrown again. Estimation was based on proportion of ground covered by the base of each plant species. This is a subjective appraisal but since all quadrats were read by one person, the data are suitable for comparison of the six fields.

Meteorological records were those recorded at the Central Experimental Farm, Ottawa, about 10 miles from the experimental plots; hence the data (Table 4) are valid for general but not detailed comparisons.

TABLE 2. — COMPARISON OF ANIMAL PERFORMANCE AND PRODUCTIVITY PER ACRE UNDER THE TWO SYSTEMS OF GRAZING

Year	Treatment	Animal gain		TDN (lb.)	Carrying capacity A.U.[1] /day	Dry matter prod. (lb.)	DM/ (lb.) gain	TDN used for gain (%)
		Total (lb.)	A.D.G. (lb.)					
1954	Fixed	214	0.97	1580	0.67	4192	19.6	30.7
	Adjusted	289	1.47	1637	0.70	4360	15.1	40.2
	Average	251.5	1.22	1608.5	0.68	4276.0	17.4	35.5
1955	Fixed	318	1.77	1684	0.87	3623	11.4	45.3
	Adjusted	411	2.48	1825	0.95	3445	8.4	53.7
	Average	364.5	2.13	1754.5	0.91	3534.0	9.9	49.5
1956	Fixed	281	1.34	1805	0.81	6068	21.6	39.4
	Adjusted	320	1.37	2035	0.91	5976	18.7	40.0
	Average	300.5	1.36	1920.0	0.86	6022.0	20.2	39.7
1957	Fixed	369	1.85	1834	0.86	4808	13.0	45.1
	Adjusted	509	2.50	2108	1.22	4530	8.9	52.9
	Average	439.0	2.18	1971.0	1.09	4669.0	11.0	49.0
4-yr. av.	Fixed	295.5	1.48	1725.8	0.80	4672.8	16.4	40.1
	Adjusted	382.3	1.96	1901.3	0.94	4577.8	12.8	46.7

[1]A.U. = Animal unit = 16 lb. TDN*

*Sylvestre, P. E., and S. B. Williams, Method of measuring the relative productivity of pasture experiments with livestock. Processed publ., Animal Husbandry Div., Exptl. Farms Service, Can. Dept. Agr. 1952.

Total digestible nutrient (TDN) production was calculated by the reverse use of feeding standards, and includes the estimated TDN requirements for maintenance and gain as listed in the publication of Sylvestre and Williams.**

An Animal Unit is equal to 16 pounds of TDN calculated by the above procedure.

Data for animal gains, DM and TDN production were subjected to analysis of variance (8).

RESULTS AND DISCUSSION

Details of experimental animals and grazing seasons are shown in Table 1.

The data on plant and animal production are shown in Table 2 and the corresponding analysis of variance for total gain, DM and TDN production are shown in Table 3. Total animal gains were consistently higher for the adjusted treatment in all years ($P = 0.01$). Average daily gain (ADG) followed a similar trend except in 1956 when rate of gain was about equal for both treatments. The relatively low rate of gain in 1956 for all treatments may be partly due to the fact that the animals were heavier than

**Sylvestre, P. E., and S. B. Williams. Methods of measuring the relative productivity of pasture experiments with livestock. Processed publ., Animal Husbandry Div., Exptl. Farms Service, Can. Dept. Agr. 1952.

TABLE 3.—ANALYSIS OF VARIANCE FOR TDN, TOTAL LIVE WEIGHT GAIN, AND DM PRODUCTION (4-year Average, 1954-1957)

Variance due to	D/F	Mean squares		
		TDN	Total live wt. gain	DM production
Treatment	1	184100**	45327**	54246
Years	3	162653**	39702**	6532738**
Replicates	2	59610*	5520*	455371
TxY	3	13894	2676	54720
TxR	2	1744	196	266243
XxR	6	6235	726	110263
TxYxR	6	10616	939	196164

* — P = 0.05
** — P = 0.01

TABLE 4. — METEOROLOGICAL DATA FOR PASTURE SEASONS 1954-1957 INCLUSIVE, AND LONG-TERM AVERAGE AT CENTRAL EXPERIMENTAL FARM, OTTAWA

Month	1954		1955		1956		1957		67-Yr. av.	
	R	T	R	T	R	T	R	T	R	T
May	2.94	53.0	1.97	58.1	3.93	48.9	1.77	53.0	2.84	54.9
June	3.67	64.6	1.70	67.2	3.02	49.6	5.71	66.0	3.39	64.5
July	1.61	66.0	1.73	73.7	3.51	65.3	1.54	68.0	3.54	69.0
Aug.	4.09	64.0	3.28	72.3	5.89	64.6	0.45	64.0	3.15	66.5
Sept.	4.91	55.6	2.19	58.2	0.81	54.2	4.56	59.3	2.98	58.4
5-month av.	3.44	60.6	2.17	65.9	3.43	56.5	2.80	62.1	3.18	62.7

R = rainfall (inches) T = temperature (°F.)

average (Table 1) when they went to pasture. It seems likely that the relatively high ADG on the adjusted treatments was primarily due to higher forage quality associated with more intensive grazing. Large differences in total gains were evident for both treatments and it is of interest that total gains were highest for all treatments in 1955 and 1957, which years had the lowest rainfall, highest mean temperature and shortest grazing season (Tables 1 and 4).

TDN production was consistently higher for the adjusted stocking treatment for all years (P = 0.01). Year differences in TDN production were also significant (P = 0.01) but did not always rank in the same order as total animal gain. For example, in 1957 total gains on both treatments were substantially higher than in 1956 but the TDN production was very similar. It does not appear that this difference was due to hybrid vigour, as the Crossbreds used in 1957 and the Shorthorns used in 1955 produced approximately the same average daily gain under similar climatic conditions. Apparently a large portion of the nutrients supplied by the pasture during 1956 were used by the cattle for maintenance; this can be related in part to the higher starting weights of the animals and the later starting date (Table 1).

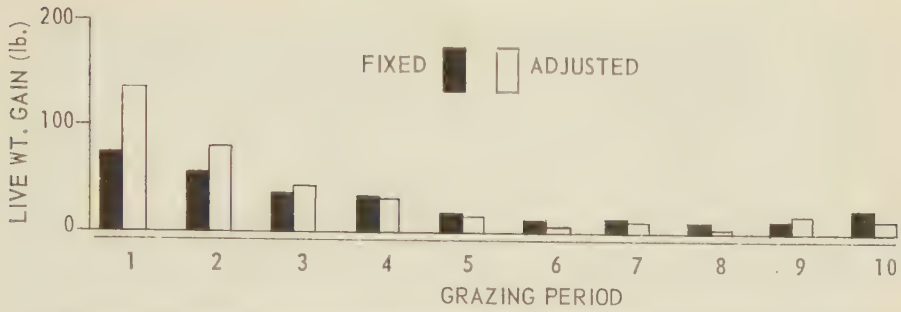

FIGURE 1. Seasonal distribution of relative live weight gain under fixed vs. adjusted stocking (4-year average, 1954-57).

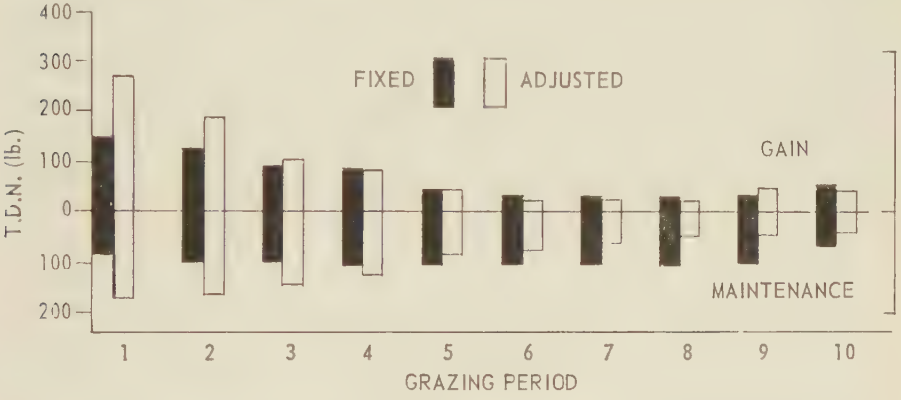

FIGURE 2. Seasonal distribution of relative proportions of TDN used for maintenance and gain under fixed vs. adjusted stocking (4-year average 1954-57).

Differences in DM production between treatments were relatively small. However, year differences were relatively large and significant ($P = 0.01$). It is of particular interest that yearly DM production did not rank in the same order as either total gain or TDN production; for example, DM production was highest in 1956 but total gain was second lowest. Exceptionally low rates of gain and inefficient utilization of TDN for gain (both treatments) in the wet years 1954 and 1956 suggest a strong grass-climate quality effect on animal performance. It is noteworthy that the rainfall for these years was relatively high and the mean temperature relatively low (Table 4). The DM total gain ratios bear this out; 17.4 and 20.2 pounds DM were required per pound gain in 1954 and 1956 as compared to 9.9 and 11.0 pounds DM in 1955 and 1957 respectively (Table 2). On well-managed pastures grazed by yearling steers at a number of stations across Canada, 8.7 pounds DM/pound gain was found to be an average figure (7).

The percentage TDN used for gain (Table 2) is a measure of efficiency of TDN utilization and is affected by animal weight and rate of gain. A higher percentage of TDN produced was used for gain in the adjusted treatment. Since most of the forage on the adjusted grazing treatment

FIGURE 3. View of one replicate of pasture layout showing difference in height of herbage on the two treatments.

was consumed early in the season when adjusted plots were heavily stocked and the animals were relatively light in weight and were consuming high quality forage, this finding is to be expected. It also provides the reason why the average carrying capacity in animal units per day was always higher for the adjusted treatment (Table 2) despite the fact that the average number of animals per acre was sometimes less (Table 1).

Differences between replicates (Table 3) were primarily due to higher yields on Replicate 1. These differences were significant ($P = 0.05$) for total gain and TDN but were not for DM production. This again suggests quality differences which can be detected in animal production but not in DM weight of clippings.

The 4-year average seasonal distribution of live weight gain is shown in Figure 1. Seventy-three per cent of the total gain for the adjusted stocking treatment was made during the first three periods (6 weeks) of the grazing season as compared to sixty per cent for fixed stocking. The drop in amount of gain as the season progressed was more gradual for fixed than for adjusted stocking. This effect was due primarily to removal of animals in the latter instance, whereas with fixed stocking it was attributed to changes in herbage quality. Quantity was not a limiting factor except for two grazing periods during September, 1957, when forage became so scarce that the animals had to be removed.

The 4-year average seasonal distribution of the TDN maintenance/gain ratio is shown in Figure 2. It is evident that during grazing periods 1 and 2 a higher proportion of the TDN was being used for gain than for

maintenance on both treatments. The reverse situation occurred in subsequent periods, a very high proportion of the TDN production from the fixed grazing treatment being used for maintenance after the fourth period. This is interpreted as resulting from a very sharp drop in quality of the forage at this point, which on the average occurs during the latter part of July. It is of interest that when Johnstone-Wallace (1, 2) clipped forage of varying heights at intervals during the season he found percentage lignocellulose increased with heights at which the plants were clipped and that forage quality, as indicated by digestibility, declined markedly. Johnstone-Wallace and Kennedy (3) also stated that in order for cows to attain maximum consumption they should have access to a dense sward not more than 5 inches high. The sward on the fixed grazing plot was over this height during much of the grazing season, as can be seen in Figure 3. The relatively low average efficiency in utilization of TDN by the fixed grazing treatment (Table 2) can be chiefly attributed to the high maintenance/gain ratio during the last six grazing periods.

The botanical composition of the pastures at the start of the experiment showed that the sward was predominantly white clover, Kentucky bluegrass and timothy. In the 1957 analysis the percentage of white clover and Kentucky bluegrass was substantially decreased. In general this was not compensated for by increases in "other plants", although Canada bluegrass did show some increase; hence there was an increase in percentage of bare ground. These changes in botanical composition appear to be about the same magnitude on both treatments. There were no clear-cut effects which could be related to changes in production of animal gains, TDN or DM.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to members of Plant Research Institute, Research Branch, for botanical analysis of the pastures, for meteorological data and for estimates of DM production of pastures. R. Holt and T. R. Knox, Assistant Herdsmen, provided valuable field assistance in the execution of the experiment.

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NOTE ON A SIMPLE MACHINE FOR MINCING LARGE CARCASSES

The machine described below is simple to build and can rapidly mince frozen carcasses of poultry, calves and pigs into fine particles which can readily be mixed into a homogeneous product.

Figure 1 shows photographs of the mincer, together with a description of its parts. It can be assembled by most workshops from locally available materials. (Detailed construction details are available from the authors).

Carcasses of calves and pigs were halved and frozen before mincing. Birds were plucked, frozen and ground whole. It is preferable to mince large carcasses in a room at 32°F. or below. At higher temperatures portions of the skin may thaw and result in coarsely shredded pieces. The tissue from birds is caught in a small metal box held in place just below the blades while the larger container shown in Figure 1 is used for large carcasses. The rate of mincing is approximately 3 pounds per minute. Once minced, the tissue is thoroughly mixed with a Hobart mixer and sampled.

The fineness of mincing was checked by washing 10-gram samples of minced tissue through 10- and 20-mesh sieves. Chips of bone remaining on the sieves were air-dried and weighed. No bone chips were removed from 10 samples of minced tissue washed through the 10-mesh sieve. The 20-mesh sieve removed 1 chip from each of 6 samples, 2 from each of 3 samples, and 3 from 1 sample. The average weight was 3 milligrams per chip. Proximate analyses of 2-gram samples of minced tissue in this laboratory have resulted in no greater differences between duplicates than ordinarily experienced in the routine analysis of finely ground feeds, feces and other materials.

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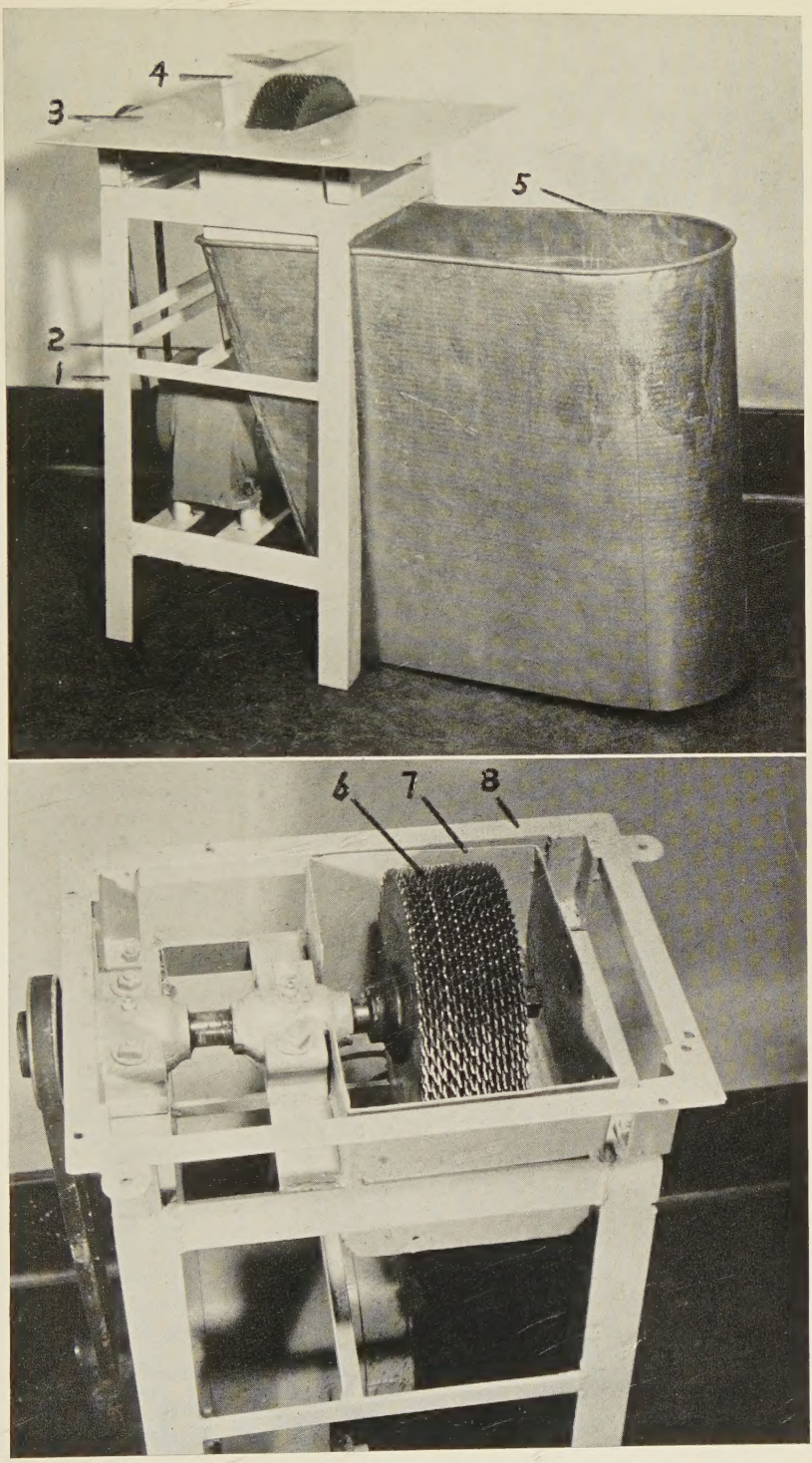

FIGURE 1. Photographs of mincer with main parts numbered.

1. Main frame: 2-inch angle iron braced with strap steel. 2. Two-h.p. electric motor (3450 r.p.m.) with 2-inch diameter V-belt pulley. 3. Table: 3/16 inch sheet steel with an opening cut to give 1/8-inch clearance on all sides of the blades. 4. Safety shield — has spring hinges on side so top can swing up. 5. Collection box: 28-gauge galvanized steel. 6. Eighteen 10-inch diameter circular saw blades, each set to 3/16 inch and held apart by washers. 7. Mince chute: 8-gauge sheet steel. 8. Table frame: 1-inch angle iron, 20 inches x 14½ inches.

NOTE ON THE EFFECT OF CITRIC ACID AND OF SODIUM CITRATE UPON THE CONSUMPTION OF PELLETED HAY BY STEERS AND UPON RATE OF PELLETING[1]

The increased consumption of hay caused by grinding and pelleting has been attributed to a faster passage of ingesta from the rumen (2). Recent work by Cullinson *et al.* (1), working with high concentrate rations in which pelleting depressed intakes, noted that pelleting depressed rumen pH. Based on the hypothesis that both these factors could be operating simultaneously while feeding high roughage rations pelleted, this trial was conducted to determine if the addition of a buffer would affect the consumption of pelleted hay by steers. The buffer selected was sodium citrate, as used by Packett *et al.* (3) in special urinary calculi-producing rations. The sodium citrate would be expected to provide a readily fermentable anion and a residual cation. Citric acid was also used to provide only the readily fermentable anion.

Twelve steers, with an average weight of 550 pounds, were divided into three groups and fed individually. All animals were fed a good quality mixed alfalfa-timothy hay, chopped to about 2 inches in length, for 2 weeks before, and for 2 weeks after, the feeding of pellets. One week was taken to gradually change the rations from chopped to pelleted hay. Complete pelleted rations were fed *ad libitum* for four 1-week periods. One group received the control pellets, the second group pellets containing 1.6 per cent citric acid, and the third group pellets containing sodium citrate at the rate of 1.6 per cent citrate equivalent. The pellets were prepared from the same hay as that fed in the preliminary period, ground in a hammermill with a 3/64-inch screen and pelleted through a 7/16-inch die.

[1]Contribution No. 75, Animal Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, Ont.

TABLE 1. — EFFECT OF CITRIC ACID AND OF SODIUM CITRATE ON THE CONSUMPTION OF PELLETED HAY BY STEERS

Period	Mean dry matter consumption per 100 lb. of body weight		
	Control group	Citric acid group	Sodium citrate group
	lb./day	lb./day	lb./day
1	2.29	2.31	2.76
2	2.64	2.74	3.08
3	2.64	2.67	3.17
4	2.98	2.70	3.36
Mean	2.63	2.60	3.09**
Increase in consumption of pellets over chopped hay	0.82	0.83	1.29

** $P < .01$

Table 1 shows that sodium citrate stimulated the intake of pellets in all periods. Citric acid had no effect. There was a tendency for consumption of pellets to increase during the four periods. When compared with the consumption of chopped hay, the consumption of pellets was greater in all groups, the sodium citrate group showing the greatest increase. There were no signs of any digestive disturbances nor anorexia throughout this trial.

The steers gained from 1.2 to 1.8 pounds per day while fed the pelleted rations but no consistent differences could be attributed to treatments in this short trial.

It was of further interest to note that the addition of these small amounts of either sodium citrate or citric acid increased several-fold the flow-rate of ground hay through the pellet machine.

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Erratum:

In the paper by Bailey *et al.* "Changes in the gross chemical composition of the mouse etc.", published in the December, 1960, issue (Vol. 40, No. 2), an error occurred in Table 1, on page 146. Under the heading "Equation", the numbers that appear after each "x" should be exponents and not simple products as shown, e.g., the first equation should be:

$$y = 0.880\ x^{0.913}\ (\textit{not}\ y = 0.880 \times 0.913)$$